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MONITORING AND EVALUATION OF SMOLT MIGRATION IN THE COLUMBIA BASIN

Volume IV: Evaluation of the 1998 Predictions of the Run-Timing of Wild Migrant Yearling and Subyearling Chinook and Steelhead, and Hatchery Sockeye in the Snake River Basin using Program RealTime

Technical Report 1999

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VOLUME IV

Evaluation of the 1998 Predictions of the Run-Timing of Wild Migrant Yearling and Subyearling Chinook and Steelhead, and Hatchery Sockeye in the Snake River Basin using Program RealTime

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Other related publications, reports and papers available through the professional literature or from the Bonneville Power Administration (BPA) Public Information Center - CKPS-1, P.O. Box 3621, Portland, OR 97208.

1998

Townsend, R. L., J. R. Skalski, and D. Yasuda. 1998. Evaluation of the 1995 predictions of run-timing of wild migrant subyearling chinook in the Snake River Basin using program RealTime. Technical Report (accepted) to BPA, Project 91-051-00, Contract 91-BI-91572.

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1997

Townsend, R. L., D. Yasuda, and J. R. Skalski. 1997. Evaluation of the 1996 predictions of run timing of wild migrant spring/summer yearling chinook in the Snake River Basin using program RealTime. Technical Report (DOE/BP-91572-1) to BPA, Project 91-051-00, Contract 91-BI-91572.

1996

Townsend, R. L., P. Westhagen, D. Yasuda, J. R. Skalski, and K. Ryding. 1996. Evaluation of the 1995 predictions of run timing of wild migrant spring/summer yearling chinook in the Snake River Basin using program RealTime. Technical Report (DOE/BP-35885-9) to BPA, Project 91-051-00, Contract 87-BI-35885.

1995

Townsend, R. L., P. Westhagen, D. Yasuda, and J. R. Skalski. 1995. Evaluation of the 1994 predictions of the run-timing of wild migrant yearling chinook in the Snake River Basin. Technical Report (DOE/BP-35885-8) to BPA, Project 91-051-00, Contract 87-BI-35885.

1994

Skalski, J. R., G. Tartakovsky, S. G. Smith, P. Westhagen, and A. E. Giorgi. 1994. Pre-1994 season projection of run-timing capabilities using PIT-tag databases. Technical Report (DOE/BP-35885-7) to BPA, Project 91-051-00, Contract 87-BI-35885.

1993

Skalski, J. R., and A. E. Giorgi. 1993. A plan for estimating smolt travel time and survival in the Snake and Columbia Rivers. Technical Report (DOE/BP-35885-3) to BPA, Project 91-051-00, Contract 87-BI-35885.

Smith, S. G., J. R. Skalski, and A. E. Giorgi. 1993. Statistical evaluation of travel time estimation based on data from freeze-branded chinook salmon on the Snake River, 1982-1990. Technical Report (DOE/BP-35885-4) to BPA, Project 91-051-00, Contract 87-BI-35885.

Preface

Project 91-051 was initiated in response to the Endangered Species Act (ESA) and the subsequent 1994 Council Fish and Wildlife Program (FWP) call for regional analytical methods for monitoring and evaluation. This project supports the need to have the "best available" scientific information accessible to the BPA, fisheries community, decision-makers, and public by analyzing historical tagging data to investigate smolt outmigration dynamics, salmonid life histories and productivity, and providing real-time analysis to monitor outmigration timing for use in water management and fish operations of the hydrosystem. Primary objectives and management implications of this project include: (1) to address the need for further synthesis of historical tagging and other biological information to improve understanding and identify future research and analysis needs; (2) to assist in the development of improved monitoring capabilities, statistical methodologies and software tools to aid management in optimizing operational and fish passage strategies to maximize the protection and survival of listed threatened and endangered Snake River salmon populations and other listed and nonlisted stocks in the Columbia River Basin; (3) to design better analysis tools for evaluation programs; and (4) to provide statistical support to the Bonneville Power Administration and the Northwest fisheries community.

The following report addresses measure 4.3C of the 1994 Northwest Power Planning Council's Fish and Wildlife Program with emphasis on improved monitoring and evaluation of smolt migration in the Columbia River Basin. This report represents the eighth in a series of technical report presenting results of applications of statistical program RealTime to present in-season predictions of the status of smolt migrations in the Columbia River Basin. Results are presented from using program RealTime to predict the 1998 in-season migration status and trend of the spring/summer-outmigration of wild yearling chinook and wild steelhead and hatchery age 1+ sockeye from Redfish Lake, and the summer-outmigration of wild subyearling chinook at Lower Granite Dam. It is hoped that making these real-time predictions and supporting data available on the Internet for use by the Technical Management Team (TMT) and members of the fisheries community will contribute to effective in-season population monitoring and assist in-season management of river and fisheries resources. Having the capability to more accurately predict smolt outmigration status improves the ability to match flow augmentation to the migration timing of

ESA listed and other salmonid stocks and also contributes to the regional goal of increasing juvenile passage survival through the Columbia River system.

ABSTRACT

Program RealTime provided tracking and forecasting of the 1998 inseason outmigration via the internet for stocks of wild PIT-tagged spring/summer chinook. These stocks were from eight release sites above Lower Granite dam, including Bear Valley Creek, Catherine Creek, Elk Creek, Lake Creek, Imnaha River, Minam River, South Fork Salmon River, and Secesh River. Forecasts were also provided for a stock of hatchery-reared PIT-tagged summer-run sockeye from Redfish Lake and for the runs-at-large of Snake River wild yearling and subyearling chinook salmon, and steelhead.

The 1998 Program RealTime performance was comparable to its performance in previous years for the whole-season evaluations for every stock tracked. Relative to 1997, performance improved for the yearling chinook run-at-large, and for predictions for last-half of the season for every other stock. Performance compared poorly with 1997 predictions for the first half of the runs of PIT-tagged yearling spring/summer chinook stocks and the run-at-large of fall subyearling chinook, and was slightly worse for the first half of the Redfish Lake sockeye run and the steelhead run-at-large. Poor first-half performance was likely due to the unusually large (and in some cases short) outmigrations in 1998.

Utilization in 1998 of a different method of adjusting smolt counts at Lower Granite Dam compared to previous years produced slightly better first-half performance than pre-1998 adjustments would have, but slightly worse last-half performance, for all the PIT-tagged stocks, prompting a return to the pre-1998 adjustment formula for the 1999 outmigration.

An Army Corp of Engineers (ACOE) experiment during April and May of 1998 involving the installation of two new components to existing structures at Lower Granite Dam did not appear to affect RealTime performance.

A comparison of run-timing predictions based on FPC passage indices and Battelle hydroacoustic counts showed the two independent data sources produced very similar results, for the wild steelhead and yearling chinook runs-at-large.

Due to the less than desirable first half performance in 1998, a refinement in the calibration process for Program RealTime will be conducted in the future.

Executive Summary

1998 Objectives

1. Refine application of program RealTime to improve precision and accuracy of in-season predictions of the run-timing of the spring/summer-outmigration of wild Snake River yearling chinook and the summer-outmigration of wild Snake River subyearling chinook at Lower Granite Dam.
2. Predict and report in real-time the “percent run-to-date” and “date to specified percentiles” of the outmigrations at Lower Granite Dam, based on the Fish Passage Center’s (FPC) passage index (wild subyearling chinook, yearling chinook, steelhead)[1] and PIT-tag detections (wild yearling chinook and hatchery-reared sockeye) from specific release sites.
3. Post on-line Internet-based predictions on outmigration status and trends to improve in-season population monitoring information available for use by the Technical Management Team and the fisheries community to assist river management.

Accomplishments

The number of release sites meeting previous years’ criteria for RealTime forecasts dropped to four for the wild spring/summer chinook parr PIT-tagged in 1997: Catherine Creek, Imnaha, Minam and South Fork Salmon Rivers. An experiment in lessening RealTime requirements was continued from 1997 which resulted in adding four release sites of spring/summer chinook: Bear Valley Creek, Elk Creek, Lake Creek, Secesh River. Passage indices provided by the Fish Passage Center for Lower Granite Dam were monitored for the wild yearling and subyearling chinook outmigrations and for the wild steelhead outmigration. Objectives for subyearling and yearling chinook, for steelhead, and for hatchery sockeye were accomplished at Lower Granite Dam. On-line run-timing predictions were provided via the Internet to the fisheries community throughout each smolt outmigration.

1. The FPC wild subyearling chinook fish passage indices at Lower Granite Dam are a mixture of wild fall chinook and small spring/summer chinook salmon, but are presumed to represent primarily fall chinook passage. Prior to 1993, some unknown fraction of hatchery produced spring/summer chinook were likely also included in the index. From 1993 on, all hatchery-produced chinook released in the Snake River Basin have been fin-clipped to confirm their origin and distinguish them from ESA listed stocks.

Findings

The 1998 Program RealTime performance was comparable to its performance in previous years with respect to the run-at-large of steelhead, and the run of hatchery-reared Redfish Lake sockeye. (The mean absolute deviance[1] (MAD) of the daily predicted outmigration-proportion from the actual outmigration-proportion is used as measure of accuracy in this and all previous RealTime reports). Performance improved for the yearling chinook run-at-large over 1997. RealTime predictions compared poorly with 1997 predictions for the first half of the runs of PIT-tagged yearling spring/summer chinook stocks and the run-at-large of fall subyearling chinook. Last-half performances for these runs compared favorably with 1997. In spite of poor first-half performance, the RealTime composite run for 1998 spring/summer yearling releases was comparable to previous years due to the improved last-half performance in 1998. Poor first-half performance is likely due to the unusually large (and in some cases early) outmigrations in 1998, coupled with a feature of the RealTime algorithm which causes predictions early in the run to be based exclusively on absolute smolt counts, rather than upon pattern-matching, which is the algorithm dynamic that dominates later in the run. The large run-sizes of PIT-tagged yearling spring/summer chinook are thought to be due to a combination of factors including favorable parr overwintering conditions and improved PIT-detection capabilities at the dam due to comparatively lower spill and flow and incremental improvements to the PIT-detection system. An explanation offered concerning the large subyearling chinook outmigration was that there was a large intermingling of spring chinook (as high as 50%) in the subyearling run, which is normally composed of fall chinook. The cause identified was the high 1997 spring chinook adult escapement. In addition it has been suggested that flow-peaks in June and July may have flushed out normally residualizing subyearling fall chinook, increasing the numbers in the subyearling run.

Other unusual conditions surrounding the 1998 outmigration include (*i*) utilization in 1998 of a different method of adjusting smolt counts at Lower Granite Dam compared to previous years, and (*ii*) an Army Corp of Engineers (ACOE) experiment during April and May of 1998 involving the installation of two new components to existing structures at Lower Granite Dam. The effects

1. Mean absolute deviance is the average absolute difference between the predicted proportion and the observed proportion of the outmigration distribution, calculated over the days in the outmigration.

of the ACOE experiment were found to be insubstantial on RealTime forecasting performance. The 1998 count adjustment formula for raw detections of PIT-tagged smolts at Lower Granite dam, while improving forecasting performance slightly over the pre-1998 formula during first half of the runs, showed a slight deterioration in performance compared to the pre-1998 adjustment process during the last half of the runs.

An opportunity to compare RealTime forecasts and predictions based on two indendent data sources availed itself in 1998. The data sources were hydroacoustic counts provided by Battelle's Pacific Northwest Division for the spring ACOE experiment, and passage indices provided by the Fish Passage Center (FPC). Predictions and performance based on the two sources were found to be very similar.

Management Implications

The ability to accurately predict the outmigration status of composite or individual salmon and steelhead stocks at different locations in the Federal Columbia River Power System (FCRPS) can provide valuable information to assist water managers. Since the 1994 outmigration, program RealTime has been applied to provide in-season predictions of smolt outmigration timing for individual and aggregates of listed threatened and endangered Snake River salmon stocks. These predictions have been made available to the fisheries community to assist in-season river management.

Accurate forecasting during the last half of the outmigrations are frequently the most crucially needed since spill decisions are based on when the run ends. Program RealTime provided forecasts for this crucial portion of the outmigrations which were comparable to 1997 performance, or improved upon it (8 out of the 10 matching 1997 runs performed better in 1998 during the last half).

Recommendations

Results from the 1998 smolt outmigrations of wild Snake River yearling and subyearling chinook, steelhead and hatchery sockeye, while very good for the last half of the outmigrations, were less than desirable for the first half. This underlines the importance of continued refinements of the statistical algorithm to effectively deal with new and unforeseen outmigration dynamics as they present themselves to the historical record. We recommend the assessment of the need for, and potential effectiveness of, a general calibration procedure for the RealTime algorithm which would perform a systematic and exhaustive search for optimal model-switching dynamics within the algorithm. Potentially, an automatic inseason calibration capability would be included which would cause the algorithm to switch to its pattern-matching portion in the face of unusually large or small initial predictions, very early in the run. In addition, the process would potentially be applied to new stocks to the RealTime enterprise, and to stocks which have been included in recent years but for which complete calibrations have not been performed.

We also recommend a return to the pre-1998 count adjustment procedure for PIT-tagged smolts in order to maximize accuracy of predictions at the end of the run. And we recommend continuing to study and monitor research and findings on the effects of river and project variables and on stock-specific biological variables, as these factors enter the count adjustment process, and as managerial and engineering enterprises continue to improve conditions for outmigrating smolts navigating hydroelectric projects in the Columbia River system.

Table of Contents

Table of Contents (continued)

List of Tables

List of Tables (cont'd)

List of Tables (cont'd)

List of Figures

List of Figures (continued)

List of Figures (continued)

Acknowledgments

We wish to express thanks to the many fisheries agencies, Tribes and other institutions that have expended considerable resources in the generation, assembly, analysis and sharing of Columbia River biological, hydrologic, operational and other related information. Deserving particular thanks are the staff of the agencies and Tribes responsible for conducting the annual Columbia River Smolt Monitoring Program, the Fish Passage Center and the Pacific States Marine Fisheries Commission PIT-Tag Information System (PTAGIS) primary database centers for providing timely in-season access to fish passage and PIT-tag information and the University of Washington second-tier database DART (Data Access in Real Time) information system which receives, processes and provides access to biological, hydrologic and operational information via the Internet. For this year's RealTime forecasting operation, we extend our special appreciation to Battelle's Pacific Northwest Division operating under the aegis of the Walla Walla District of the Army Corps of Engineers, for providing hydroacoustic data on passage abundance of wild yearling chinook and steelhead at Lower Granite Dam.

Special appreciation is extended to Judy Cress and Peter Westhagen of the School of Fisheries at the University of Washington for providing critical data management and computer programming support.

Funding support for this work came from the Pacific Northwest region's electrical ratepayers through the Columbia River Fish and Wildlife Program administered by the Bonneville Power Administration.

1.0 Introduction

Regulating the timing and volume of water released from storage reservoirs (often referred to as flow augmentation) has become a central mitigation strategy for improving downstream migration conditions for juvenile salmonids in the Columbia River Basin. Snake River water managerns in particular have used flow augmentation to improve the outmigration survival of stocks listed as threatened or endangered under the Endangered Species Act (ESA). Timing the release of water so that the listed stocks are in place to encounter these augmented flows requires knowledge of the status and trend of the stocks' outmigration timing.

In 1993, work was begun under this project to develop real-time predictions of smolt outmigration dynamics for ESA-listed stocks and other runs-at-large for the Snake and Columbia Rivers. The fruit of this labor was the Program RealTime, a statistical software program which predicts run-timing of individual stocks of salmonids (Skalski et al. 1994). It uses historical data to predict the percentile of the outmigration that will reach an index site, in real-time---and it forecasts the elapsed time until some future percentile is observed at that site. The first in-season predictions were of wild spring/summer chinook from the Snake River drainage above Lower Granite Dam in their 1994 outmigrations. These fish originate in streams listed by the National Marine Fisheries Service (NMFS) as evolutionary (evolutionarily/ecologically) significant units (ESUs). As parr, a portion of them are annually implanted with PIT (Passive Integrated Transponder, Prentice et al., 1990a, b, c) tags, and released back into their natal streams where they overwinter until their outmigration as yearlings in the spring and summer (Achord et al. 1994, 1995, 1996, 1997, 1998). During outmigration, PIT-tag detectors at Lower Granite Dam read codes in the tags specific to the smolts' release site, so individual stocks can be monitored.

University of Washington fisheries scientists subsequently incorporated Program RealTime predictions into their CRiSP model to move the forecasted runs of these stocks down the Snake River to Little Goose, Lower Monumental and McNary Dams (Hayes et al. 1996, Beer et al. 1999, *http://www.cqs.washington.edu/crisprt*).

Since 1994, the RealTime forecasting enterprise has expanded to track and forecast other NMFS-listed populations of Snake River salmonids. In addition to the wild yearling spring/summer chinook ESUs, program RealTime currently tracks and forecasts the run-timing to Lower Granite Dam of runs-at-large of wild Snake River subyearling chinook, yearling chinook and steelhead, and a population of hatchery-reared PIT-tagged, summer-run sockeye from Redfish Lake (Townsend et al. 1995, 1996, 1997, 1998.)

This report presents a post-season analysis of Program RealTime performance for 1998. Here we compare RealTime predictions with observed distributions of fish counts at Lower Granite dam. During the outmigration season, predictions are interactively accessible, daily, via the World Wide Web at address *http://www.cqs.washington.edu/crisprt.* The website's end-of-season graphical and tabular displays of Program RealTime results, by stock, are included in appendices A and B of this report. Appendix A contains the daily record of RealTime predictions compared with the season-end observed distributions for all runs tracked by Program RealTime in 1998, and Appendix B contains current and historical run-timing information.

2.0 Methods

2.1 Description of Data

2.1.1 PIT-tag Data

In 1998 we tracked and prepared forecasts of outmigration timing to Lower Granite Dam for PIT-tagged wild yearling spring/summer chinook, and an outmigration of age 1+ hatchery-reared, PIT-tagged summer-run sockeye from Redfish Lake.The wild yearling chinook originated from eight release sites: streams above Lower Granite dam, where they were captured, PIT-tagged, and released as parr (Figure 1 and Table 1).

Figure 1: Map showing PIT-tag/release sites forecasted and tracked by Program Real-Time in 1998. All sites produced wild yearling spring/summer chinook except Redfish Lake which was the release site of hatchery-reared sockeye. Wild parr were captured, PIT-tagged, and released during summer and fall of 1997 at these streams , and tracked at Lower Granite Dam during spring and summer of 1998.

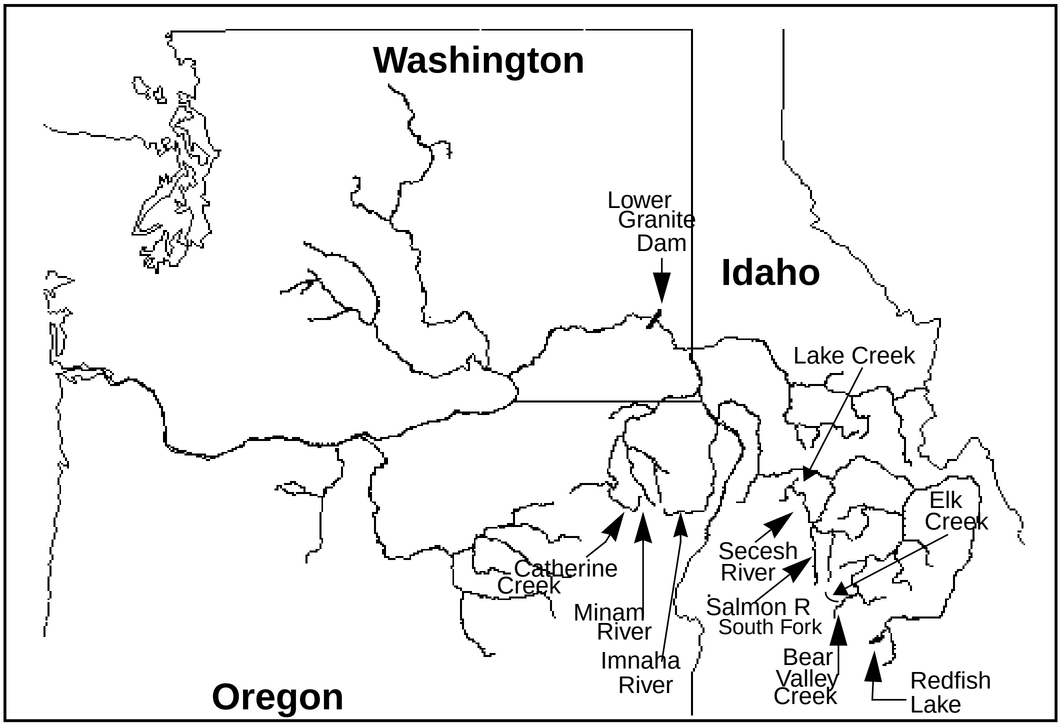


Table 1: The PIT-tag/release sites included in the 1998 Program RealTime forecasting. PIT-tagged parr were released at these sites in 1997, and tracked and forecasted to Lower Granite Dam during spring and summer of 1998.

Stream Name (Release Site)	GIS Hydrounits[a]
Bear Valley Creek	17060205
Catherine Creek	17060104
Elk Creek	17060205
Imnaha River	17060102
Lake Creek	17060208
Minam River	17060106
Redfish Lake	17060201
Salmon River, South Fork	17060208
Secesh River	17060208

a.Geographical Information System (GIS) designations established by the U.S. Geological Survey.

2.1.2 Passage Index Data

Forecasts and tracking of outmigrational timing at Lower Granite Dam were provided for the runs-at-large of Snake River wild subyearling fall chinook, wild yearling spring/summer chinook, and wild steelhead.

Passage index data is made available by the Northwest Power Planning Council’s (NWPPC) Fish Passage Center (FPC). Passage indices are not population estimates, but do reflect the size of the runs. They are collection counts divided by the proportion of water passing through the sampling system. The collection counts are counts made under FPC sampling plans (FPC, 1999).

2.1.3 Hydroacoustic Data

Hydroacoustic fish-detection equipment, provided by Battelle’s Pacific Northwest Division, was installed at Lower Granite dam to count fish and monitor their behavior during the 1998 outmigration. The data was primarily used by the Army Corps of Engineers to analyze the effects of some experimental protocols. It provided an independent source of run passage size during the spring and summer of 1998.

2.2 RealTime Data Requirements, Other Data Criteria, Composites.

2.2.1 PIT-tag Data

Program RealTime predicts on the basis of historical information. Originally, streams were chosen on the basis of their consistent recovery numbers (PIT-detections at LGR)[1], and by virtue of having at least three years of historical data, each with at least 30 PIT-tag detections. Over the years, we’ve studied streams with less historical information in order to determine whether a lower standard would still provide good forecasts. In addition we studied “composite runs”, the combined data from several streams treated as a single stock. The composite runs are “good performers” (produce good predictions) because they smooth and cancel individual-stock randomness. They can be useful for providing general run-timing information about groupings of release sites. In 1998 there were two composites, the “RealTime composite” and an “all-stocks composite.” RealTime-composite sites had to meet the original, more stringent data requirements,

1.Detections of PIT-tagged smolts at Lower Granite Dam can be seen as recaptures or recoveries in a mark-release experiment, so the terms “recapture”, “recovery”, and “detection” will be used interchangeably throughout this report.

while the all-stocks composite admits all comers. In 1998, the RealTime composite streams were Catherine Creek, and the Imnaha, Minam and South Fork Salmon Rivers (Figure 1, Table 1).

In order to ensure representative sampling of the wild yearling spring/summer stocks, it was established this year that only Lower Granite PIT-detections of fish tagged and released by experienced taggers Paul Sankovitch and Steve Achord would be used by RealTime. Parr whose tags are implanted by inexperienced taggers or for other experimental protocols could bias the sample. Also, to maintain consistency between pre- and post-1993 PIT-tagging practices (after 1993, tagging continued into late fall and winter, Ashe, B.L. et al. 1995, Blenden, M.L. et al. 1996, Keefe et al. 1995, 1996), we used only detections of fish tagged from May 31 through November 1 of the previous year, since fish marked during different seasons have shown differences in migrational timing to Lower Granite Dam (Keefe et al. 1995, 1996).

Redfish Lake sockeye PIT-detections were restricted to fish tagged and released between July 31 and December 31 of the previous year, to ensure consistency of recoveries.

2.2.2 Passage Index Data

In 1995 the run-at-large of subyearling fall chinook was added to the RealTime tracking and forecasting enterprise. The RealTime algorithm was modified (see Models section) to incorporate information on migrational timing characteristics (Connor et al. 1993, 1994a, 1994b, 1996; Giorgi and Schlechte 1997; OWICU 1996; Smith et al. 1997) and behavioral characteristics (Nelson et al. accepted; Rondorf et al. 1993, 1994a, 1994b, 1996; Connor et al. 1992, 1997, in preparation-a,b; Garcia et al. in preparation; Marshall et al. 1998, in preparation; Tiffan et al. in preparation-a,b) specific to subyearlings. We use passage indices provided by the FPC (Section 2.1.2) to track subyearlings because agencies refrain from PIT-tagging naturally-produced subyearling chinook in the Snake River system due to low stock abundance.

In 1996, it was established that only years subsequent to and including 1991 would be used as reference (historical) years for forecasting subyearling run-timing. Before 1991 hatchery and wild subyearlings were not differentiated in the counting process and environmental conditions were substantially different (Townsend et al. 1998b). Also, only data after June 1 would be used since it is too difficult to differentiate by outward appearance wild subyearling chinooks from small wild spring/summer yearlings during this overlap in their outmigrations. Such miscountings would not be important later in the season, but they can potentially make a large difference in the shape of the timing distribution at the beginning of the run (Conner et al. 1993).

In 1997 we began tracking both wild steelhead and wild yearling chinook runs-at-large using passage indices.

To maximize historical information, each day of the current run is added to historical-year data so that today's prediction is based not only on previous years' data, but on yesterday's data as well.

2.3 Preprocessing.

Raw PIT-tag count data is adjusted (Section 2.4) and smoothed---using three 5-day smoothing passes to filter out statistical randomness---before it gets to the RealTime forecaster algorithm. Raw passage index data is not adjusted but is smoothed the same as PIT-data. Passage indices are flow-adjusted by the FPC (Section 2.1.2).

2.4 Adjustment of Raw PIT-tagged Smolt Counts.

Because some PIT-tagged smolts pass Lower Granite Dam undetected by the dam's PIT-tag detection system, for example through the spillway, the daily number of fish observed, "raw smolt counts" is multiplied by an expansion factor, resulting in "adjusted counts":

raw counts x expansion factor = adjusted counts.

It is the adjusted counts which program RealTime uses, and these, as well as the raw counts are interactively accessible during the outmigration at the worldwide website. In previous years the expansion factors were estimates of

$$\frac{1}{1-SE} \tag{1}$$

where *SE* is *spill effectiveness*, the fraction of smolts passing undetected through the spillway.

In 1998, two changes were made to the adjustment process, based on research using PIT-tag recovery probabilities to estimate spill effectiveness and fish guidance efficiency (FGE, fraction of fish passing through the dam's fish guidance system, see section 2.5) for chinook and steelhead at Lower Granite Dam (Skalski and Perez-Comas, 1998). Firstly, a proportional hazards model,

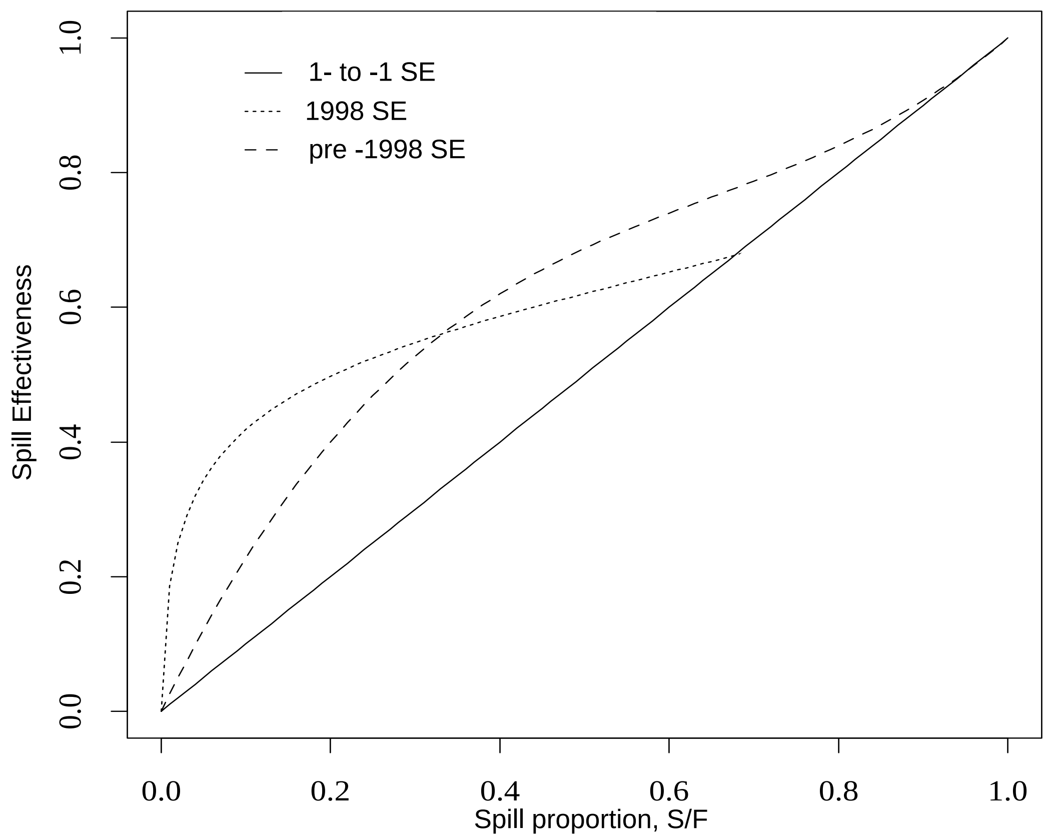
$$SE = \begin{cases} \alpha_0^{\exp\left(\left(\alpha_1 \log\left(\frac{S/F}{1-S/F}\right)\right)\right)}, & S/F \in [0,0.6] \\ S/F, & S/F > 0.6 \end{cases}$$

replaced previous years' cubic equation (Wilson et al. 1991, Smith et al. 1993),

$$SE = 1.667\left(\frac{S}{F}\right)^3 - 3.25\left(\frac{S}{F}\right)^2 + 2.583\left(\frac{S}{F}\right),$$

where, in both formulas, S is daily spill during the outmigration, F is flow (Figure 3), and S/F spill proportion, the daily proportion of total water volume through the spillway, and $\alpha_0 = 0.6203$, and $\alpha_1 = -0.2738$ (Figure 2).

Figure 2. Spill effectiveness (SE) functions used by Program RealTime to upwardly adjust raw PIT-tag detections. Shown are the 1998, pre-1998 and 1-to-1 formulas for spill effectiveness as a function of spill proportion (volume spilled/volume of flow).



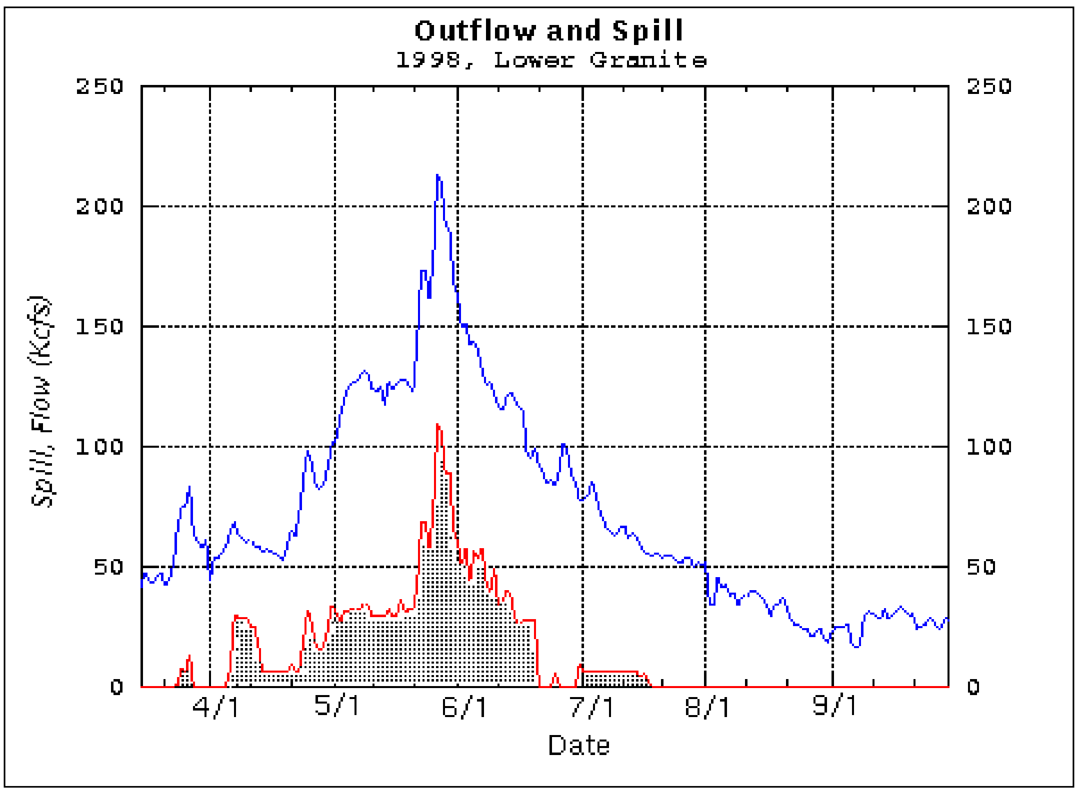
The dotted curve in Figure 2, this year's formulation, reflects evidence that spill effectiveness increases as a function of spill proportion (S/F) up to about 0.2 and then tapers off, becoming equivalent to a one-to-one function of spill proportion at around 0.6 (Skalski and Perez-Comas, 1998).

Secondly,the expansion formula (1) itself was modified to eqn. 2, below. The new formula is based on a combination of spill effectiveness and fish guidance efficiency. The FGE for chinook is given by

$$FGE = 0.2 + 0.6\beta_0^{\exp\left(\left(\frac{\beta_1}{1000}\right)F + \beta_2 T\right)},$$

where F is daily flow, T temperature and $\beta_0 = 0.5352$, $\beta_1 = -16.6509$, and $\beta_2 = 0.1264$ (Skalski and Perez-Comas, 1998).

Figure 3: Total flow and spill at Lower Granite Dam for April-November, 1998.



The effect of the new expansion formula,

$$\frac{1}{1-SS} \cdot \frac{1}{FGE}, \qquad (2)$$

is to further adjust the raw smolt count upward, particularly as temperatures rise through the summer months (Figures 4, 5).

In previous years *FGE* was not included in the adjustment process because it was assumed constant and as such, would not affect predictions. Figure 4 displays the 1998 daily expansions based on the old (eqn.1) and new (eqn. 2) formulas. The 1998 expansions are tabled in Appendix C of this report. Figure 5 shows the new and old adjustment methods applied to Elk Creek and South Fork Salmon River data.

Figure 4. Comparison of the 1998 daily expansions, calculated using previous years' (pre-1998) expansion formula (eqn. 1 in text) and current (1998) expansion formula (eqn. 2 in text). The expansions are multiplied by raw smolt counts (PIT-detections) to get adjusted counts. Values for 1998 expansions are given in Appendix C.

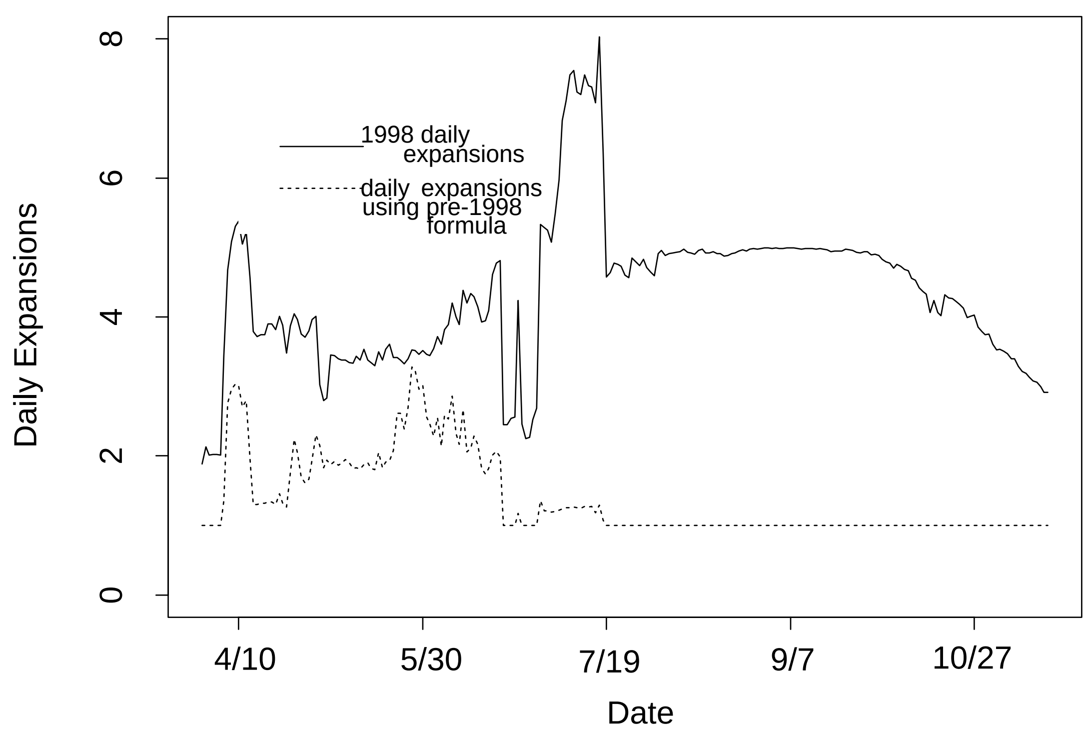
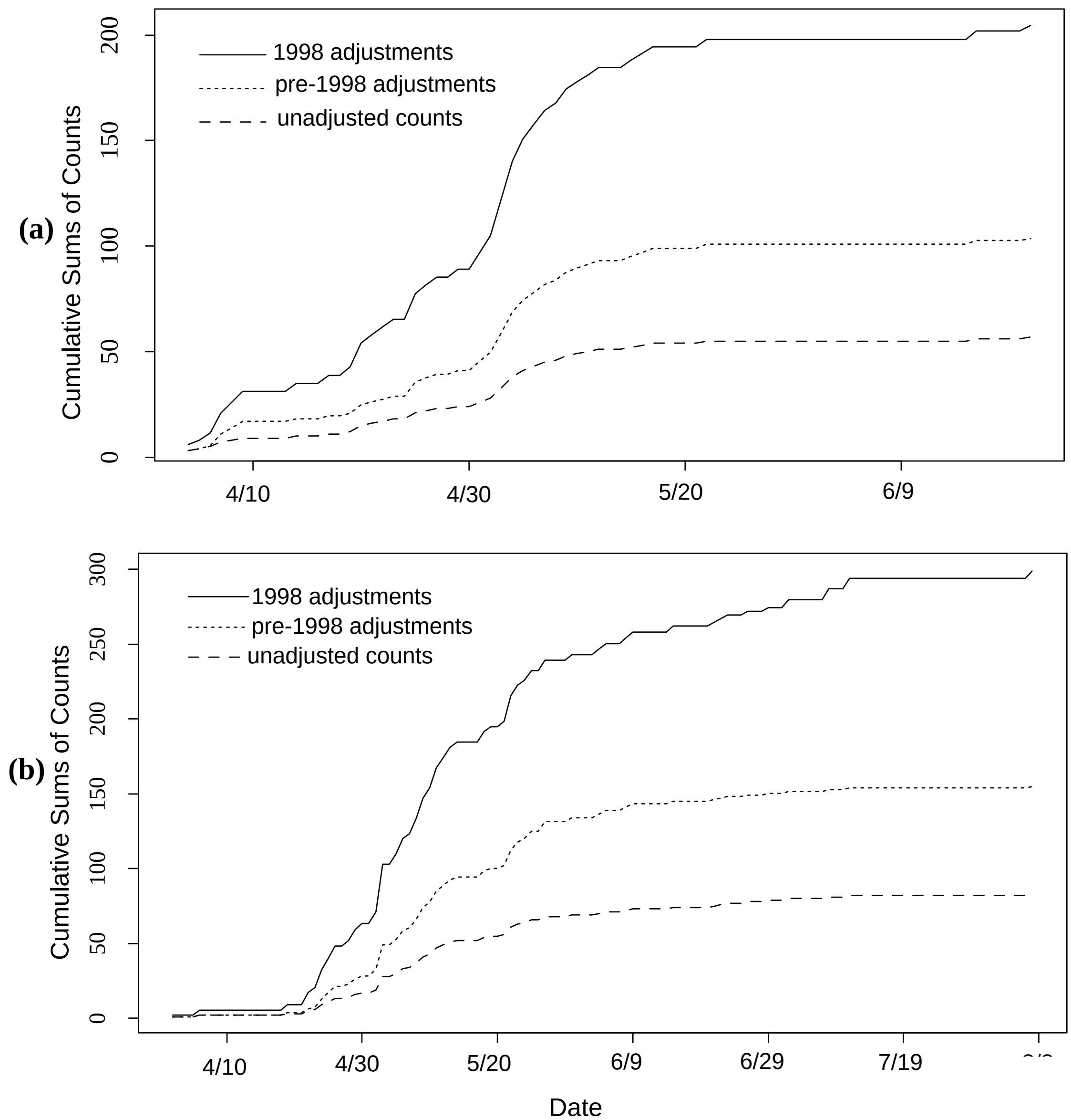


Figure 5. Cumulative sums of adjusted counts of smolts detected at Lower Granite dam, originating from (a) Elk Creek, and (b) Salmon River, South Fork, using different adjustment formulae (see text). Solid lines are adjusted data using 1998 formula (eqn.2), dotted lines are adjusted using pre-1998 formula (eqn. 1), and dashed lines are raw data (unadjusted by any expansion formula).



2.5 River Conditions.

2.5.1 Conditions at Lower Granite Dam

In the spring of 1998, the Army Corps of Engineers (ACOE) installed, on an experimental basis, two new components to existing structures at Lower Granite Dam, *i*) a behavioral guidance system (BGS), and *ii*) a Simulated Wells Intake (SWI) device retrofitted to the dam's surface bypass collector (SBC). The components were slated for permanent installation subject to positive research results from the Corp's study which began April 13 and ended May 31, 1998. The expectation was that the components would reduce entrainment of salmonid smolts into the turbines by re-routing fish passage to alternate channels.

The research period coincided with a substantial portion of the outmigrating run of yearling chinook and Redfish Lake sockeye including the first appearance of fish at the dam at the beginning of the runs in the spring. Because of this, a brief discussion of the ACOE experiment will be included in this report.

Smolt Passage at LGD. Prior to 1998, smolt passage through Lower Granite Dam could occur in six ways. Fish could go 1) through any of the six turbines, 2) through a fish guidance system in the turbine intakes which diverted fish away from the turbines by means of submerged screens, 3) through the surface bypass collector (SBC) installed at the entrance of the dam's north turbines (4-6), 4) through the spillway located immediately north of the SBC, 5) through the navigation locks, and 6) through the adult fish ladders (Johnson et al. 1999, Earl Prentice, pers. comm., 1999). The only route of the six that detects and counts PIT-tagged smolts is the fish guidance system.

New Components at LGD. The behavioral guidance system (BGS) is a 335-m long steel wall attached to the south side of the SBC (between turbines 3 and four) and upriver near the south shore, whose purpose is to divert fish away from the south-shore turbines (1-3), and toward turbines 4-6, which have the SBC attached at the entrances. The BGS was moved in and out of the river every third day during the experimental period in order to test for its effectiveness in diverting fish, and for its effects on other systems at the dam, and on fish behavior. Its potential for affecting RealTime performance lay primarily in its possible effects on fish guidance efficiency, the proportion of fish using the turbine bypass routes where fish are counted.

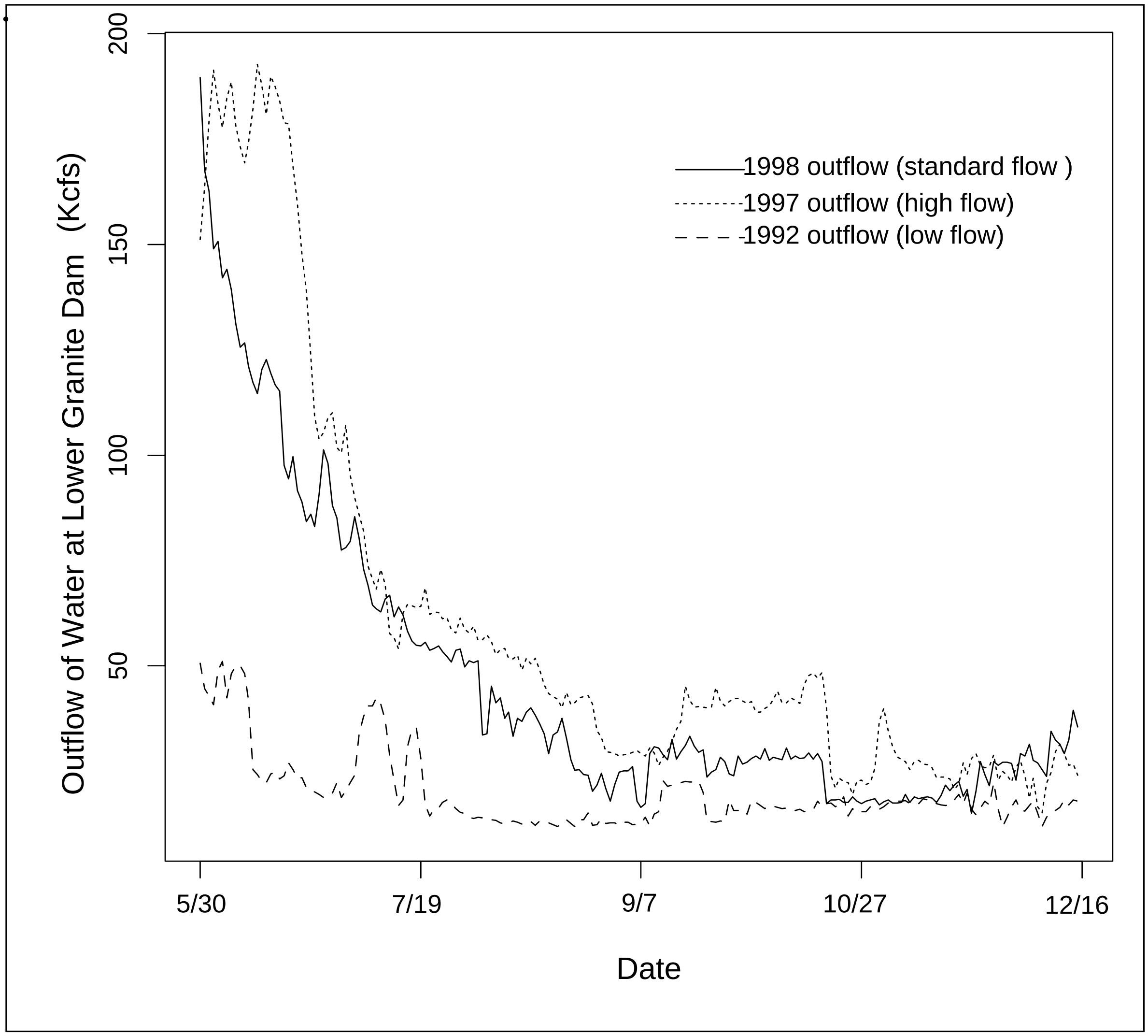
The simulated wells intake (SWI) is an attachment to the SBC which changes the collector's shape and size and is designed to flatten the water flow in front of the SBC and thereby increase the number of fish entering it.

2.5.2 Flow and Spill

Figure 3 shows outflow and spill for the 1998 season. Flow and spill can affect fish behavior and passage at Lower Granite dam (Johnson, et al. 1999).

Although it has not been conclusively demonstrated, flow (which is highly correlated with a number of other river variables, such as turbity and temperature) is thought to substantially affect wild subyearling chinook outmigration timing to Lower Granite Dam (Connor, et al. 1994b and 1996; Giorgi and Schlechte 1997; Smith et al.1997). Flow surges may influence the numbers of fry that migrate from upriver spawning grounds (Healey, 1991). Flow peaks in June and July may have been responsible for the early migration of some subyearlings that would otherwise residualize and migrate as yearlings (William Connor, USFWS, pers. comm., 1999). The 1998 flow year was not as high as recent years and was treated as a standard flow year (Figure 6). That is, separate daily predictions based on similar-flow historical years were not performed in 1998 as they were in 1997, which was a high-flow year. RealTime predictions for subyearlings based on similar-flow years may be substantially better than predictions based on all historical years (Townsend, et al. 1998c).

Figure 6. Flow at Lower Granite Dam from May 30 - December 15, for 1992, 1997, and 1998.



2.6 Migration Year 1998.

The migration year 1998 was notable in that all eight of the wild yearling spring/summer chinook release sites recorded a higher-than-average percentage of recaptures[2] at Lower Granite dam, and, for five sites, 1998 showed the highest recapture percentages on record (Tables 2 and 3). Observed concurrently with these high recovery rates of PIT-tagged yearling chinook was a normal-sized run-at-large of yearling chinook as counted by passage indices (Table 4). Improved

2.See footnote 1.

.

Table 2: Historical recovery percentages for the release sites used in predicting wild yearling chinook smolt run-timing by program RealTime in 1998. PIT-tagged parr were released during summer and fall of 1997 from these sites, and tracked at Lower Granite Dam during spring and summer of 1998. Recovery percentages are (#tags detected)/(#tagged parr released at Lower Granite dam) per site.

Year	Release Sites[a]							
	Bear Valley Creek	Catherine Creek	Elk Creek	Imnaha River	Lake Creek	Minam River	Salmon River S. Fork	Secesh River
1989	---	---	---	6.0	7.7	---	3.8	9.8
1990	5.8	---	---	8.0	---	---	---	7.2
1991	12.5	7.6	12.9	5.4	---	---	9.9	7.0
1992	6.6	7.1	7.8	9.6	---	---	7.9	3.9
1993	6.6	9.2	6.7	6.3	10.6	10.5	10.1	9.2
1994	9.9	7.6	7.6	11.7	6.7	11.1	7.6	7.6
1995	5.1	9.8	5.0	4.0	6.2	7.0	5.0	5.8
1996	---	6.9	---	9.7	---	6.8	2.3	4.6
1997	---	8.7	---	9.6	5.3	8.3	5.1	13.1
1998	13.8	8.8	23.1	15.7	11.5	12.3	8.2	12.6

a.Data from Columbia Basin Research Data Access in Real Time (DART), www.cqs.washington.edu.

PIT-detection at Lower Granite Dam would provide a partial explanation for the large recovery rates as well as the discrepancy between PIT-detections and passage indices. Improved PIT-detection may occur when spill and flow are relatively low (Gene Matthews, NMFS, e-mail. comm. and William Connor, USFWS, e-mail comm.) as they were during the first portion of the runs of PIT-tagged yearling chinook. Improvements to the detection system itself, including installation of more detectors has been an ongoing process for several years and could help to account for observations. In addition it is thought that "...several factors came together at once... to produce what will likely be an...upper bound...of expected detection rates" (Gene Matthews, NMFS, e-mail communication, 1999). Matthews suggested that a set of conditions favorable to parr over-wintering survival, including a relatively mild winter with normal snowpack in the mountains, was primarily responsible for the high detections.

Table 3: Summary of wild yearling chinook (and Redfish Lake hatchery-reared sockeye) release recapture information used by program RealTime in 1998 showing (1) number of PIT-tagged parr released in 1997 by site, (2) detected number of smolts by site at Lower Granite Dam (raw smolt counts), (3) adjusted smolt counts (Section 2.4) (4) number of years of historical data for each site, (5) average of historical (adjusted) recapture percentages ($\bar{r} \times 100$) and (6) (adjusted) recapture percentage for 1998 (column 3/column 1).

Tagging Location	(1) 1997 Parr Pit-tagged	(2) 1998 PIT Detections	(3) Adjusted PIT Detections	(4) Years of Historical Data	(5) Average Historical Recapture Percentages $\bar{r} \times 100$	(6) 1998 Recapture Percentages[a]
Bear Valley Creek	427	59	212.9	6	20.3	49.9
Catherine Creek	495	43	155.2	7	23.5	31.4
Elk Creek	246	57	204.4	5	20.5	83.1
Imnaha River	1010	159	579.1	9	20.9	57.3
Lake Creek	418	48	174.1	5	18.5	41.7
Minam River	998	123	454.3	5	24.4	45.5
Redfish Lake	4692	71	145.6	3	5.6	3.1
Salmon River, SF	1007	83	299.2	8	17.6	29.7
Secesh River	588	74	269.3	9	19.9	45.8

a.Data Sources: PTAGIS Database and RealTime program output as of 22 September 1998.

Table 4: The total passage index numbers of wild runs-at-large counted at Lower Granite Dam.

Year	Subyearling Chinook (after June 1)	Steelhead	Yearling Chinook
1990	---	698242	---
1991	13,672	628771	---
1992	5,744	583740	---
1993	16,620	583457	374138
1994	6,765	517244	334022
1995	26,046	485203	865290
1996	17,548	525732	214106
1997	17,561	435069	80861
1998	82,498	754499	373736

Concurrent with high detection rates was a smaller than average number of PIT-tagged fish released at Bear Valley Creek, Catherine Creek, and Elk Creek (compare table 3 releases with Bear Valley Creek's historical average of 988 released parr; Elk Creek's 770; and Catherine Creek's 1110, see Appendix B). In addition, several sites had unusually early and short outmigrations in 1998 (Appendix B).

Numbers of subyearling fall chinook smolts counted by the Fish Passage Center at Lower Granite Dam were also remarkably large in 1998, compared to previous years (see Table 4). A large flow peak in June/July may have been responsible for flushing out some subyearlings that would normally residualize, remaining in their natal streams and migrating as yearlings the next year (William Connor, USFWS, pers. comm.). More importantly, genetic research Connor conducts annually led him to conclude that as much as half of the subyearling run, normally composed of fall chinook were, in fact, spring chinook in 1998. The apparent cause was a high escapement of spring chinook in 1997 (William Connor, pers. comm.). Another contributor may have been a mild winter favorable to high egg survival and/or high egg-to-fry emergence. Higher than average steelhead passage indices may also be partially accounted for by the favorable environmental conditions that led to the large yearling and subyearing chinook runs.

2.7 Models

2.7.1 Introduction: the LS Algorithm

At its introduction in 1994, the RealTime Forecaster was exclusively a pattern-matching algorithm which matched current-year fish passage data with historical cumulative percentage passage curves, by comparing their slopes. At the beginning of the outmigration, when there was very little in the way of a current-year pattern to match, the predictions were inaccurate compared to the predictions later on in the season. In the 1994 post-season analysis, an alternative model was tested for its performance during this initial phase of the outmigration. This "start-up" model was based on the estimated run-percentage on a given day of the outmigration. This model was found to perform better than the pattern-matching model at the beginning of a run, but deteriorated in performance later on, when the pattern-matching model excelled. A method of weighting the two model predictions during the season was then developed. This switching model was an age-of-run model based on the mean fish run age (MFRA). By incorporating the run-percentage and age-of-run information, the RealTime algorithm effectively bound these indicators together with the pattern matching model into a single, more accurate and robust predictor. The pattern-matching model uses a least-squares computation, and the algorithm has retained the name "Least Squares (LS) Algorithm" because of its original structure, and other than the inclusion in 1996 of a separate switching scheme for subyearlings, the current version is nearly identical to the previous three years[3].

The LS Algorithm predicts for each day of the outmigration, for each individual stock studied, an estimate, $\hat{P}$, of the true percentile, P, of the stock's outmigration that has passed Lower Granite dam to date. The basic mathematical function of the algorithm is to minimize a total error quantity,

$$\sum_{i=1}^{N} Err_i(p),$$

with respect to p such that

$$\hat{P} = \min_{p}\left[\sum_{i=1}^{N} Err_i(p)\right], \qquad p = 0, \ldots, 100, \tag{3}$$

where i indexes historical years $1, \ldots, N$, and

$$Err_i(p) = \left(1 + \frac{LSE_i(p)}{LSE_i(p) \times MFRA_i(p) + 200.0}\right) \times \tag{3a}$$

$$\left(1 + \left[\frac{1}{\left[\frac{MFRA_i(p)}{12} + \frac{\hat{P}_{RP}}{25}\right]^2} \times RPE(p)\right]^2\right) \times \left(1 + \frac{ARE_i(p)}{50.0}\right)$$

for the yearling spring/summer chinook smolt outmigration, and

3.The LS algorithm was referred to as the New Least Squares (NLS) algorithm in the 1995 report to distinguish it from the original form of the LS algorithm used for the 1994 outmigration season.

$$Err_i(p) = \left(1 + \frac{LSE_i(p)}{LSE_i(p) \times MFRA_i(p) + 200.0}\right) \times \tag{3b}$$

$$\left(1 + \left[\frac{1}{\left[\frac{MFRA_i(p)}{8} + \frac{\hat{P}_{RP}}{16}\right]^2} \times RPE(p)\right]^2\right) \times \left(1 + \frac{ARE_i(p)}{50.0}\right)$$

for the summer/fall outmigration of subyearling chinook. The quantities $LSE_i(p)$, $\hat{P}_{RP}$, $RPE(p)$, $MFRA_i(p)$, and $ARE_i(p)$ are defined and discussed in the sections below.

2.7.2 The Pattern-Matching or Least-Squares Model and $LSE_i(p)$

The pattern-matching portion is accomplished by a least-squares (LS) model, where the patterns are cumulative percentage curves of outmigrating smolts. Current-year data are compared with historical cumulative percentage curves by comparing their slopes at each percentile, $j = 1, \ldots, 100$, using the measure

$$LSE_i(p) = \sum_j (s_j - s_{ijp})^2 w_{ijp}, \tag{4}$$

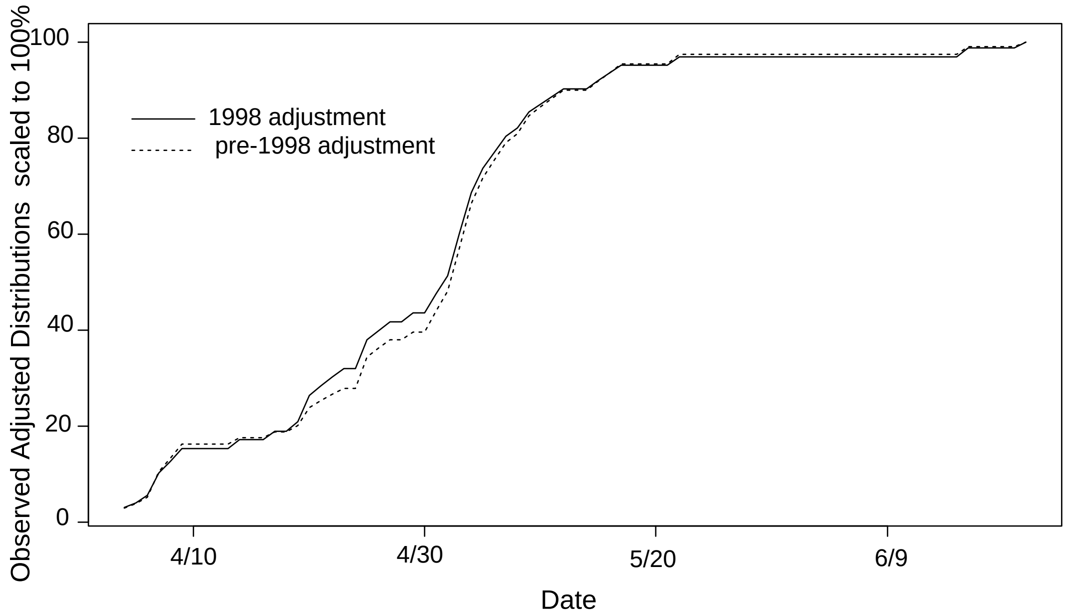
where s_j is the slope at the j^{th} percentile of current-year data to-date and s_{ijp} is slope at the j^{th} percentile of p percent of historical year i 's outmigration curve, and w_{ijp} is defined below. The value of p that minimizes (4), i.e.,

$$\hat{P}_{LS_i} = \min_p \left[\sum_{j=1} (s_j - s_{ijp})^2 w_{ijp}\right], \qquad p = 0, \ldots, 100 , \tag{5}$$

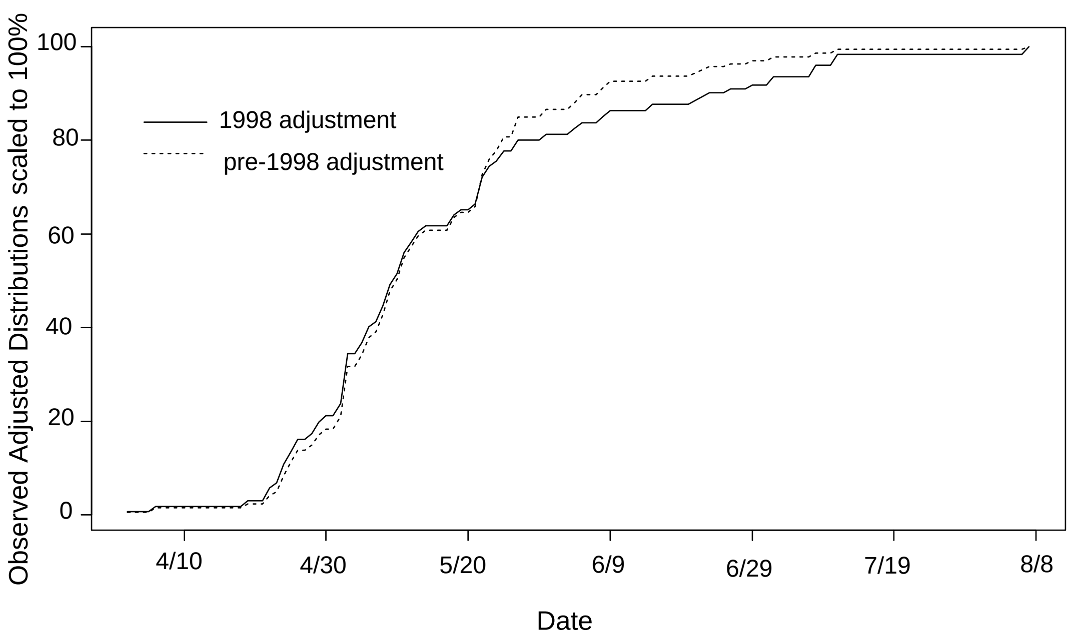
is the best predictor from the point of view of pattern-matching to historical year i. Note that comparing Figures 5 and 7 shows how normalizing cumulative sums of fish counts to 100% converts very different-looking patterns to very similar cumulative percentage curves. Figure 7 shows the cumulative percentages of the daily smolt counts in Figure 5.

Figure 7: Smolt counts at Lower Granite Dam for (a) Elk Creek, and (b) Salmon River, South Fork, adjusted using 1998 formulation and pre-1998 formulations for daily expansions, and scaled to 100%.

(a)



(b)



The weight, w_{ijp}, is computed as

$$\frac{D_j + D_{ijp}}{R + R_{ip}}$$

where D_j is the estimated number of days between the (j-1)th and jth percentile for the current year, D_{ijp} is the number of days between the (j-1)th and jth percentile for historical year i for the first p percent of the outmigration, R is the number of days in the current outmigration to date, and R_{ip} is the number of days in the first p percent of historical year i's outmigration. The effect of w_{ijp} is to give more weight to the errors generated in the tails of the distribution, where the slopes tend to be flat and the number of days between each percentage point is high. Less weight is given to the mid-season, when large numbers of fish detected on a daily basis will create a steep slope in the cumulative distribution. The total sum of the weights adds to one. Note that the LS *model*'s weighting factor, w_{ijp}, is not the same as the weighting scheme used by the LS *Algorithm*.

The LS model has optimal performance when there are large numbers of fish and the slope of the observed distribution is fairly steep.

2.7.3 The Start-Up or Run Percentage Model and $RPE(p)$

The start-up model, used for initial predictions at the beginning of the outmigration, produces run-percentage (RP) estimates of P:

$$\hat{P}_{RP} = \frac{x_d}{E(\hat{S})}, \tag{6}$$

where x_d is the total number of fish observed by day d of the outmigration, and $E(\hat{S})$ estimates the total expected outmigration to Lower Granite dam for the individual stock. The expectation is estimated differently, depending on the type of data. For PIT-tagged stocks, $E(\hat{S})$ is equal to $\bar{r}$ x N, where $\bar{r}$ is the average historical recapture percentage (detections divided by "releases", the number of PIT-tagged fish released at a particular site per year) at Lower Granite dam, and N is total releases the previous year for PIT-tagged stocks. Table 3 displays the information used by program Realtime to compute these estimates. For passage index data, $E(\hat{S})$ is simply the average historical run.

size. Table 4 displays these estimates for yearling and subyearling chinook salmon and steelhead trout runs-at-large.

The RP model is based on an average of historical-year information, thus the absence of a subscript *i* for year in RP error,

$$RPE(p) = \left| \log p - \log \hat{P}_{RP} \right|, \quad p = 0, \ldots, 100 .$$

The LS Algorithm will tend to choose a value of p close to $\hat{P}_{RP}$ early in the run when $\hat{P}_{RP}$ is small, and *RPE*(p) is weighted lightly.

2.7.4 The Switching Model or Age-of-Run Model and $ARE_i(p)$

The switching model is an age-of-run (AR) model and is a weighting instrument that enables the LS Algorithm to shift from RP predictions to LS predictions appropriately. The age-of-run model estimates passage percentile P as

$$\hat{P}_{AR} = p \text{, such that } MFRA_i(p) = MFRA, \quad p = 0, \ldots, 100$$

where

$$MFRA_i(p) = \frac{\sum_{d_i = 1}^{n_i(p)} [fish_{d_i} \times (n_i(p) + 1 - d_i)]}{\sum_{d_i = 1}^{n_i(p)} fish_{d_i}} , \qquad (7)$$

and $fish_{d_i}$ is the number of fish observed on day *d* of historical year i, and $n_i(p)$ is the number of days until the percentile p of the outmigration is observed during year *i*. Current-run *MFRA* is calculated as

$$MFRA = \frac{\sum_{d = 1}^{n} [fish_d \times (n + 1 - d)]}{\sum_{d = 1}^{n} fish_d} .$$

That is, current-year $MFRA$ is computed as in (7), except that current $MFRA$ cannot be written as a function of p since that is unknown on any given day n of the current run, so $n(p)$ is simply n. The estimate of the error of $\hat{P}_{AR_i}$ is

$$ARE_i(p) = \left| \log(p) - \log(\hat{P}_{AR_i}) \right|, \qquad p = 0, \ldots, 100. \tag{8}$$

and this, as well as $MFRA_i(p)$, is included in the total error terms (3a,b), contributing day-to-day abundance information to the algorithm.

Early in the outmigration, when $\hat{P}_{RP}$ and $MFRA_i(p)$ are small, the algorithm will tend to choose the RP model estimate. The larger $\hat{P}_{RP}$ and $MFRA_i(p)$ are, the less the RP method dominates and the more the LS method takes over in estimating run timing.

2.7.5 Precision of Estimator: Confidence Intervals for $\hat{P}$

Each day of the run, a jackknife confidence interval is constructed for the daily prediction estimate. Jackknifing is a computer-intensive method of extracting sampling distribution information about an estimator by recomputing the estimator from different subsets of the sample data, here the historical data. A jackknife subset consists of the complete set of historical years minus one. If a release site has, say, 6 years of historical data, there will be 6 subsets of 5 years each. A prediction estimate is computed from each subset, and these jackknife estimates provide a measure of standard error on which the daily confidence interval is based.

2.6.6 Evaluating RealTime Performance

The true outmigration percentile on day d, (i.e., P_d), can only be observed after the run is finished (i.e. $P_{last} = 100\%$). When the run is over, we evaluate RealTime's performance using the mean of the absolute differences (MAD) between observed outmigration percentiles, P_d, and their estimates, $\hat{P}_d$, for all days, d:

$$MAD = \frac{\sum_{d=1}^{n} \left| \hat{P}_d - P_d \right|}{n} \tag{9}$$

where n is the total number of days in the outmigration run for the season.

3.0 Results

3.1 Wild PIT-tagged yearling spring/summer chinook

The 1998 outmigration of wild yearling spring/summer PIT-tagged chinook was unusual in several respects, including record high percentages of detected fish at Lower Granite Dam (section 2.6), installation of structures intended to change fish passage behavior at Lower Granite (section 2.5), and utilization of a different method of adjusting raw smolt counts upward (section 2.4).

Table 5 compares the 1997 and 1998 mean absolute deviations (MADs) for the entire outmigration, and for the first and last halves of the outmigration of pit-tagged wild yearling spring/summer chinook. The MADs, which evaluate Program Realtime predictions, show that 1998 performed similarly to 1997 for the outmigration taken as a whole, but worse during the first half and better on average during the last half of the outmigration. The RealTime composite-run predictions werewithin 3% of the observed percentile (MAD was 2.6%) for the entire run in 1998. The first half of the outmigration showed an increase in the RealTime composite MAD from 2.3% in 1997 to 6.7% in 1998; during the second half the MAD decreased from 1.7 to 1.5%. Two of the four streams making up the Realtime composite showed dramatic increases in MADs during the first half of the season: Imnaha River first-half MAD was 20.6%, up from 6.3% in 1997, and Minam River increased from 2.0% to 16.3%. Last-half performance improved substantially however for Minam River (down to 3.5% from 10.9% in 1997) and Salmon River, South Fork (down from 6.6% to 3.4%). The mean MAD of all release sites for the first half of the run was 15.1%, up from 6.1% in 1997, but the last half decrease from 8.2 to 5.6% compensated, resulting in a mean MAD of 8.4% compared to 7.7% in 1997. Every stream for which comparisons were available with 1997 showed larger first-half MADS and smaller second-half MADs, with the exceptions of Catherine Creek and Imnaha River.

Table 5: Comparison of mean absolute deviances (MADs) for applicable 1997 and 1998 release sites and comparison of RealTime composite MADs for wild yearling chinook smolts. Columns show percent MAD's for the entire run, the first 50% of the run, and the last 50% of the run (to two weeks after last detection). Sites in bold are RealTime Composite release sites.

	1997			1998		
Tagging Site	Total Run	First 50%	Last 50%	Total Run	First 50%	Last 50%
Bear Valley Creek	---	---	---	8.0	8.6	7.7
Catherine Creek	7.4	7.9	7.1	8.4	7.6	8.8
Elk Creek	---	---	---	12.5	26.8	6.4
Imnaha River	3.2	6.3	2.2	10.6	20.6	4.5
Lake Creek	10.2	1.0	11.8	8.7	19.7	6.1
Minam River	8.3	2.0	10.9	7.8	16.3	3.5
Salmon River, South Fork	6.5	6.0	6.6	4.3	6.6	3.4
Secesh River	7.3	9.1	7.1	6.5	14.8	4.5
mean MAD[a]	7.7	6.1	8.2	8.4	15.1	5.6
median MAD[a]	7.3	6.1	7.1	8.2	15.6	6.3
range[a]	3.2 - 13.9	1.0 - 11.0	2.2 - 15.7	4.3 - 12.5	6.6 - 26.8	3.4 - 8.8
mean MAD of RealTime composite sites[b]	6.4	5.6	5.1	7.8	12.8	6.7
Composite Run[c]	1.8	2.3	1.7	2.6	6.7	1.5

a.These statistics are based on all release sites for a given year. Some of the 1997 release sites are not shown here.
b.This statistic based on RealTime Composite sites only: Catherine Creek, Imnaha River, Minam River, and Salmon River-SF, for both years.
c.Combined data from RealTime composite sites, processed as a single population.

Figure 8 and Table 6 compare the percentile-passage dates of the individual stocks, the RealTime composite run and the all-stocks composite made up of all the ESU stock PIT-tagged during the previous summer. Figure 9 shows the distance in river kilometers of the release sites above Lower Granite Dam. The middle 80% of the RealTime composite run contains the 50th percentile for all the release sites. A lagging of migration timing for longer migration distance is not apparent this year, since some of the most distant streams (Elk Creek and Bear Valley in particular) had unusually early runs. Appendix B contains detailed historical outmigration information for each of the 8 release sites.

Figure 8: RealTime Composite-run: daily predictions with jackknifed confidence intervals compared to the observed run.

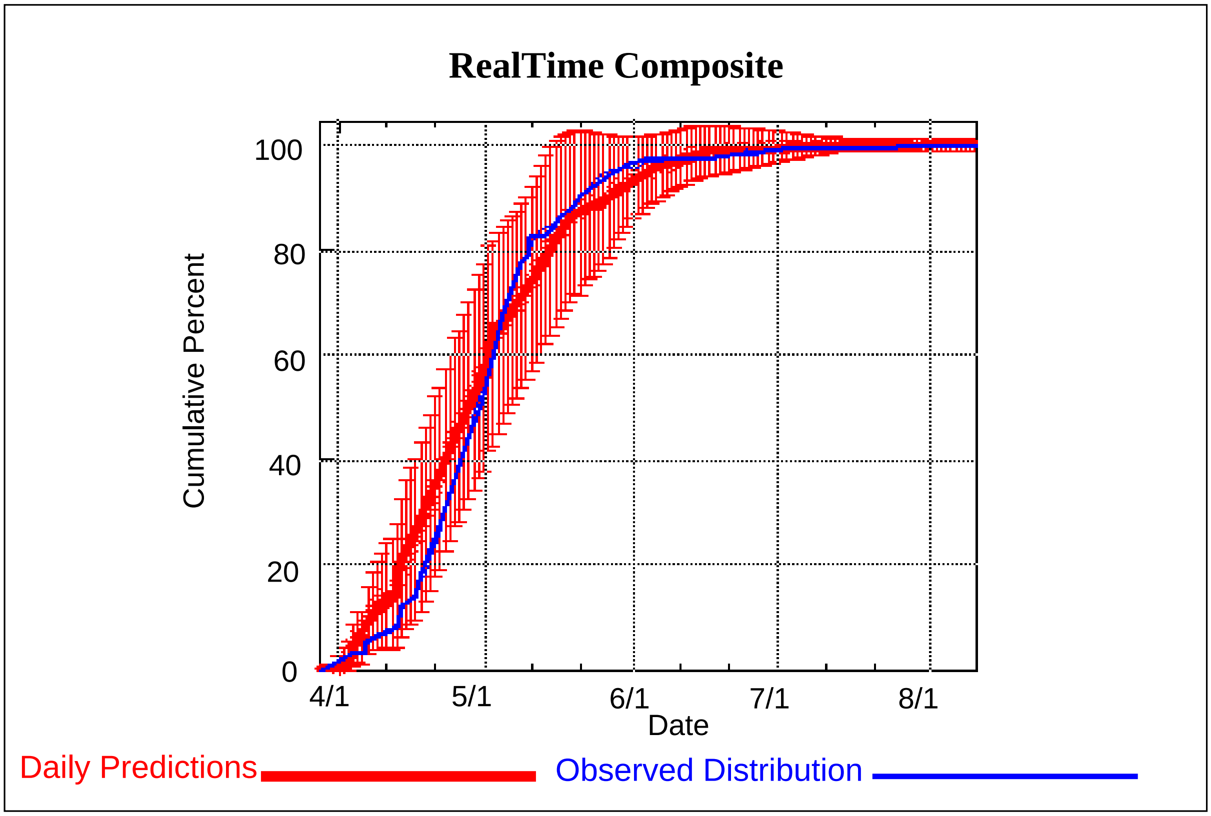


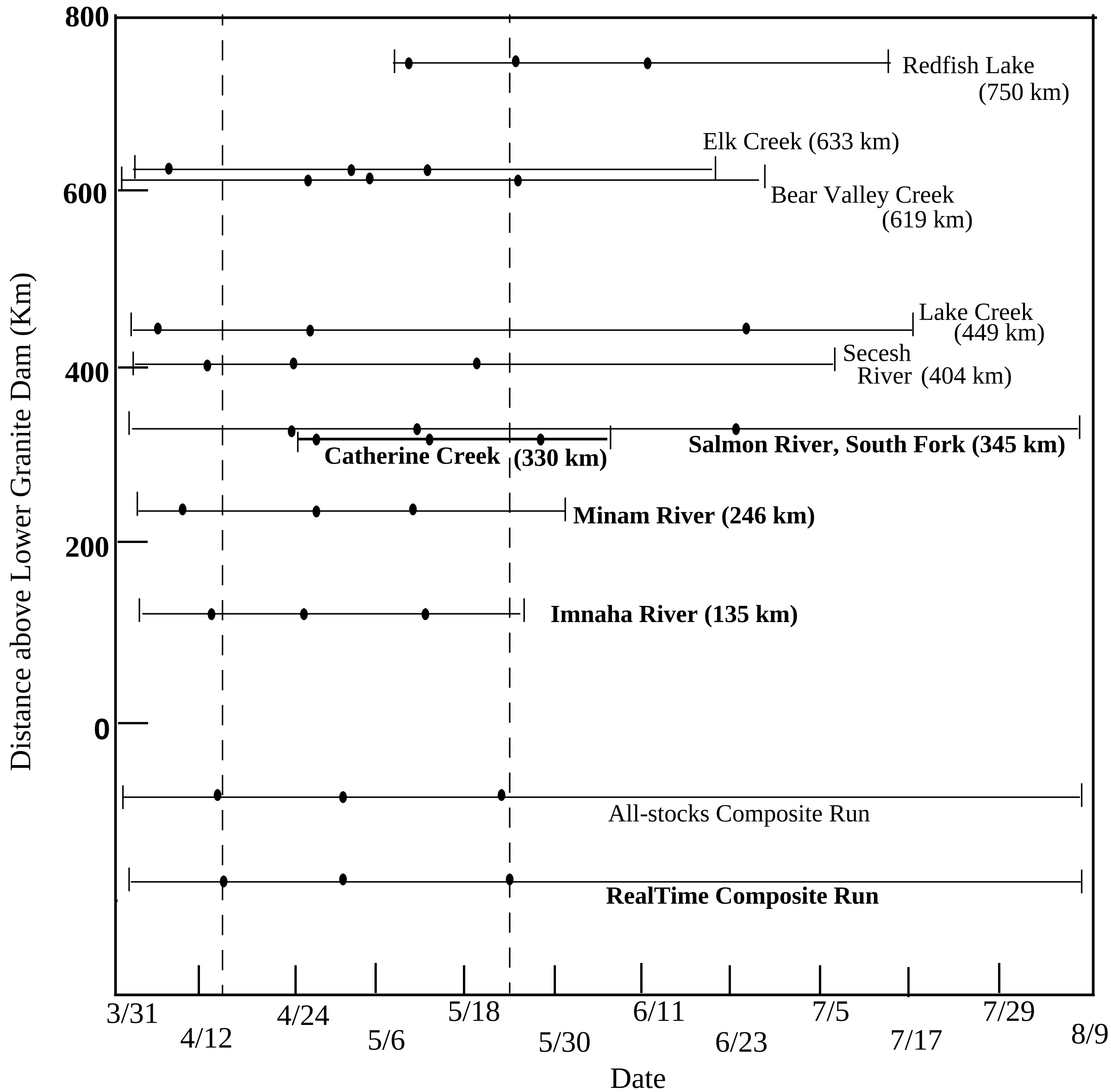
Table 6: Observed passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam in 1998 for PIT-tagged wild Snake River spring/summer chinook salmon smolts for the eight release sites, and for the RealTime and all-stocks composite runs. The smolts were PIT-tagged as parr in 1997.

	Passage Dates at Lower Granite Dam			
Population or Stock	10%	50%	90%	Range
Bear Valley Creek	4/25	5/04	5/23	3/31-6/25
Catherine Creek	4/26	5/12	5/27	4/24-6/04
Elk Creek	4/07	5/02	5/12	4/04-6/21
Imnaha River	4/14	4/28	5/13	4/03-5/24
Lake Creek	4/05	4/25	6/25	4/02-7/16
Minam River	4/09	4/27	5/10	4/03-5/30
Salmon River, South Fork	4/24	5/10	6/23	4/02-8/07
Secesh River	4/13	4/24	5/19	4/03-7/06
Program RealTime Composite[a]	4/15	5/01	5/22	4/02-8/07
All-stocks composite[b]	4/14	5/01	5/22	3/31-8/07

a. The RealTime Composite includes the release sites Catherine Creek, Imnaha, Minam and South Fork Salmon Rivers, those streams that met RealTime historical criteria defined in the text.

b.The All-stocks composite combines data from all 8 release sites.

Figure 9. Timing plot of 1998 passage dates (10%, 50%, 90% (dots) and range (endpoints)) at Lower Granite Dam for wild Snake River yearling chinook smolts tagged and released as parr in 1997 from the 8 sites;for the RealTime and All-stocks composites; and for Redfish Lake sockeye. Dashed lines show dates that 10% and 90% of outmigration passed Lower Granite Dam as estimated by the RealTime composite run. Sites in bold were included in the RealTime composite. Vertical axis gives distance in river kilometers of release sites to Lower Granite Dam.



3.2 Redfish Lake Sockeye

Redfish Lake sockeye are summer-run fish that are hatchery-reared. The 1998 outmigration was somewhat earlier in 1998 than in previous years (Appendix B). Unlike the chinook outmigrations Redfish Lake sockeye were underpredicted by RealTime in the first half of the season and overpredicted in the second half (Figure A5, Appendix A). Like the chinook runs, MADS were higher in the first half than in 1997 (12.3% compared to 6.1%) and lower in the second half (4.9% in 1998 compared to 7.5% in 1997) resulting in an overall reduction in MAD size down to 6.3% from 7.3% (Table 7).

Table 7: Comparison of mean absolute deviances (MADs) for the 1997 and 1998 passage indices at Lower Granite Dam of PIT-tagged Redfish Lake sockeye smolts. Columns show percent MADs for the entire run, the first 50% of the run, and the last 50% of the run (to two weeks after completion of run).

	1997			1998		
Run	Total Run	First 50%	Last 50%	Total Run	First 50%	Last 50%
Redfish Lake Sockeye	7.3	6.1	7.5	6.3	12.3	4.9

3.3 Wild Subyearling Chinook Run-at-Large

Like the 1998 yearling spring/summer chinook PIT-tagged stocks, subyearling passage numbers were unusually large this year compared to previous years (Table 4). Also, like the PIT-tagged yearling stocks, first-half MADS for the subyearling run are much larger in 1998 than in 1997 or previous years. The MAD for the first-half of the run was up from 5.0 in 1997 to 21.1 this year. Last-half MADs were improved from last year, down from 8.6 to 3.6, making the total 1998 full-run MAD comparable to 1997: 8.6% compared to 7.6% in 1997. Run-timing characteristics for 1998 subyearlings were unremarkable (Appendix B).

Table 8: Comparison of mean absolute deviances (MADs) for the 1997 and 1998 passage indices at Lower Granite Dam of wild subyearling chinook smolt, and Redfish Lake hatchery-reared sockeye smolts. Columns show percent MADs for the entire run, the first 50% of the run, and the last 50% of the run.

	1997			1998		
Run-of-Year	Total Run	First 50%	Last 50%	Total Run	First 50%	Last 50%
Wild Subyearling Chinook	7.6	5.0	8.6	8.2	21.1	3.6
Wild Yearling Chinook	9.0	8.9	9.0	1.8	6.4	1.0
Wild Steelhead	1.6	1.9	1.6	1.0	2.7	0.6

3.4 Wild Yearling Chinook and Steelhead Runs-at-Large

The wild yearling chinook run size was unremarkable. The steelhead run size was larger than average (Table 4). The MADs for these runs were smaller and showed smaller differences between first- and last-half MADs than the runs discussed in the previous three sections. While the first-half MAD for yearling chinook was larger than the last-half MAD, it was still an improvement upon 1997 performance which showed comparatively large first- and last-half MADs. Steelhead MADs for both halves and the whole-run were remarkably good for both years. While the 1998 total run-size showed a 35% increase from the historical average of steelhead, the RealTime algorithm still performed very well. The larger first-half MAD for the yearling chinook is not due to large poor initial predictions since the RR-model predictions were very good for this run (Appendix A).

The reasons for the discrepancy in size between the large PIT-tagged yearling chinook outmigrations and the average-sized passage index yearling spring/sumer chinook outmigration are not well-understood. Presumably these spring/summer yearling chinook all originated from the same 1996 spawner escapement which was normal-sized.

3.5 Comparison of model performance using FPC passage indices and Battelle hydroacoustics.

Hydroacoustic data on fish passage were available from Battelle's Pacific Northwest Division in 1998, because of their role in counting fish and monitoring fish behavior for the spring ACOE experiment at Lower Granite dam (Section 2.5). Thus we had the opportunity to compare two independent sources of total fish passage data for the steelhead and yearling chinook outmigrations: the Battelle data and data from the Fish Passage Center (FPC) (Table 9). The two information sources give similar predictions relative to the observed distributions.

Table 9: Comparison of mean absolute deviances (MADs) between RealTime predictions for the runs-at-large of wild steelhead and yearling chinook and there observed distributions based on Fish Passage Center (FPC) passage indices with Battelle hydroacoustic counts at Lower Granite dam in 1998. Columns show percent MADs for the entire run, the first 50%, and the last 50% of the run.

	Battelle			FPC		
Species	Total Run	First 50%	Last 50%	Total Run	First 50%	Last 50%
Steelhead	1.4	2.4	1.1	1.0	2.7	0.6
Yearling Chinook	1.7	6.1	0.8	1.8	6.4	1.0

4.0 Discussion

This report has detailed several unusual aspects of the 1998 RealTime tracking and forecasting enterprise. Firstly, there were unusually large outmigrations for some of the runs tracked. Secondly, there was an experiment conducted concurrently with some of the outmigrations at Lower Granite Dam involving the installation of two new components at the dam. In particular the BGS trials were designed to change fish guidance at Lower Granite dam every third day during the course of the spring outmigration. Thirdly, we introduced a new formula for adjusting PIT-detected smolt counts upward. And finally, Program RealTime predictions were unprecedentedly poor for some of the runs during the first half of the outmigration, although improved accuracy in the last half produced overall performances combarable to previous years.

When we look for the reasons for the poor first-half performance of Program RealTime, we find that the high smolt counts alone can account for these results, and the other two factors are incidental. The effects of the new components at Lower Granite Dam designed to reduce turbine entrainment and increase SBC passage do not appear to be an important explanation for high PIT-detection rates. While the new components installed there (Section 2.5) did reduce turbine entrainment and increase passage through the SBC, passage through the PIT-tag detection system (FGE) appears to have been substantially unchanged (Johnson, et al. 1999). A reconstruction of the forecasted runs, using the old, pre-1998 adjustment formula produced patterns very similar to those found under the new (1998) expansions. In fact, there were even larger first-half overpredictions, while the last-half underpredictions were somewhat smaller (Table 10).

Table 10: Comparison of mean absolute deviances (MADs) produced from different adjustments of the 1998 PIT-detection data for yearling spring/summer chinook stocks at Lower Granite Dam. Columns on the right side contain MADs calculated from RealTime predictions using 1998 data adjusted by the expansion formula used prior to 1998 (eqn. 1). Left-side columns (headed 1998) are as in Table 5 (from eqn. 2 adjustments). Columns show percent MAD's for the entire run, the first 50% of the run, and the last 50% of the run (to two weeks after last detection). Sites in bold were included in RealTime Composite.

Tag/Release Site	1998			1998 Runs With Pre-1998 Adjustment		
	Total Run	First 50%	Last 50%	Total Run	First 50%	Last 50%
Bear Valley Creek	8.0	8.6	7.7	6.6	9.0	5.3
Catherine Creek	**8.4**	**7.6**	**8.8**	**11.0**	**14.2**	**8.8**
Elk Creek	12.5	26.8	6.4	14.3	36.2	4.4
Imnaha River	**10.6**	**20.6**	**4.5**	**11.1**	**22.2**	**3.5**
Lake Creek	8.7	19.7	6.1	7.0	22.1	3.4
Minam River	**7.8**	**16.3**	**3.5**	**7.8**	**15.8**	**3.0**
Salmon River, South Fork	**4.3**	**6.6**	**3.4**	**3.3**	**7.2**	**1.8**
Secesh River	6.5	14.8	4.5	6.1	17.6	2.6
mean MAD	8.4	15.1	5.6	8.4	18.0	4.1
median MAD	8.2	15.6	6.3	9.4	16.7	3.5
range	4.3 - 12.5	6.6 - 26.8	3.4 - 8.8	3.3 - 14.3	7.2 - 36.2	1.8 - 8.8
Composite Run[a]	**2.6**	**6.7**	**1.5**	**2.4**	**7.8**	**1.0**

a. The composite for 1998 consists of the release sites from Catherine Creek, Imnaha, Minam and South Fork Salmon Rivers. These were the releases that met all RealTime selection criteria.

Table 11 underlines the difference in the magnitudes of 1998 recapture rates compared to historical averages for PIT-tagged yearling spring/summer chinook. Recovery rates increased by 134% on the average in 1998 over previous historical years.

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Table 11: Percent increase of 1998 recapture percentages relative to historical average ($\bar{r} \times 100$) by release site for wild yearling chinook smolts recaptured (detected) at Lower Granite dam and tagged and released as parr the previous summer.

Release site	Average Historical Recapture Percentages $\bar{r} \times 100$	1998 Recapture Percentages[a]	Percent increase in 1998 recapture percentage compared to historical average ($\bar{r} \times 100$)
Bear Valley Creek	20.3	49.9	146
Catherine Creek	23.5	31.4	37
Elk Creek	20.5	83.1	305
Imnaha River	20.9	57.3	174
Lake Creek	18.5	41.7	125
Minam River	24.4	45.5	86
Salmon River, South Fork	17.6	29.7	69
Secesh River	19.9	45.8	130

a.Data Sources: PTAGIS Database and RealTime program output as of 22 September 1998.

What follows is an explanation of how unexpectedly large smolt counts and recapture rates can cause the large initial overpredictions seen in Program RealTime forecasts this year.

Because RealTime calls into play the RR model predominantly at the beginning of the season, predictions are close to $\hat{P}_{RR}$ initially (Section 2.7.3). Table 12 displays the values of $\hat{P}_{RR}$ for the first day of the run for each of the eight release sites, along with 1998 day-one predictions, and actual day-one passage percentiles observed after the completion of the run. One can see from these figures that it is RR-model dynamics that are driving the overpredictions and dictating their magnitudes.

The most extreme first-half overprediction was seen in Elk Creek. The adjusted recapture rate was 83.1% compared to a historical average of 20.5% over 5 years (Table 3). Its low release numbers, 246 parr, multiplied by the estimated recapture proportion, .205, produce an expected run size of 50.4. Three fish were observed on April 4, day-one of the Elk Creek run. The expansion factor for that day (Appendix C) was 2.02, making 6.06 adjusted day-one fish. Thus $\hat{P}_{RR}$ was

$12.0 = (6.06)/(0.205 \cdot 50.4)$. The RealTime prediction of passage percentile based on this data was 13.7% while the observed percentile for this day after the run was completed was 3.0. By studying figure A2 (Appendix A), one can observe the algorithm trying to correct for the overprediction as it changes over to the pattern-matching (LS) model (sections 2.7.1, 2.7.2). Elk Creek predictions dipped several times in an effort to correct.

Table 12: RR-model estimates, P_{RR} (col. 4), for day-one of 1998 outmigration of wild yearling chinook, along with observed day-one percentiles (col. 5=col.1/col.3) and day-one RealTime predictions (col. 6) for all release sites---showing dominant RR-model dynamics and trend of first-half overprediction.

Release site	(1) Adjusted day-one fish, $x_d = x_1$	(2) Expected (adjusted) run size: $\bar{r} \times N$	(3) Observed (adjusted) 1998 total run size (TOT)	(4) $\hat{P}_{RR} = \frac{x_1}{\bar{r} \times N}$ (1)/(2)	(5) Observed day-one percentile: x_d /TOT (1)/(3)	(6) RealTime day-one prediction
Bear Valley Creek	1.88	86.7	212.9	2.2	0.9	2.1
Catherine Creek	7.74	116.3	155.2	6.7	5.0	7.5
Elk Creek	6.06	50.4	204.4	12.0	3.0	13.7
Imnaha River	8.08	211.1	579.1	3.8	1.4	4.0
Lake Creek	4.02	77.3	174.1	5.2	2.3	5.8
Minam River	2.02	243.5	454.3	0.8	0.4	0.9
Salmon River, SF	2.01	177.2	299.2	1.1	0.7	1.1
Secesh River	4.04	117.0	269.3	3.5	1.5	3.5

The explanation of RealTime anomalous behavior in 1998 provided in the Elk Creek example above serves to explain the same phenomenon seen in the subyearling fall chinook run-at-large outmigration. Here again we see the unexpectedly high counts and low expected run-numbers, leading to initial overprediction due to RR-model dynamics.

Possible explanations for the large subyearling and PIT-tagged yearling chinook runs have been discussed (Section 2.6) but it is not well understood why the large run sizes were not also reflected in the yearling chinook run-at-large (Tables 4 and 9).

The Redfish Lake sockeye outmigration is different from the chinook in some ways and similar in others. The similarities are: poor initial predictions driven by RR-model dynamics (recapture percentage deviates from historical expectation), and fairly good last-half predictions (Table 7). The difference is that Redfish Lake sockeye are underpredicted in the first half and overpredicted in the last half because in this case the recapture rate is smaller than average. With 4692 tagged parr released in 1997, only 71 detections were made at Lower Granite in 1998: a recovery rate of 3.1%, 45% smaller than the historical average.

5.0 Recommendations

The results of this years tracking and forecasting of run-timing events for endangered or threatened stocks of salmonids in the Snake River system suggest the need for additional refinements in order to maintain or improve the reliability of inseason predictions made by Program RealTime. These include *i)* assessment of the need for and potential effectiveness of a systematic calibration process for Program RealTime. Such a process could potentially improve performance by providing a better timing mechanism for model-switching within the algorithm (see Models section), *ii)* return to the pre-1998 count adjustment procedure for PIT-tagged smolts in order to maximize accuracy of predictions at the end of the run. Continue to monitor research on fish passage as a function of species, river conditions and dam structures.

5.1 Model Calibration

A preliminary study into the possible effectiveness of an automatic calibration procedure for RealTime's model-switching mechanism is recommended. Such a calibration procedure would systematically and exhaustively search for the best weighting mechanisms for switching from RR model dynamics to LS model dynamics (Models section) in order to optimize performance for new and existing runs in the RealTime forecasting enterprise. This preliminary assessment would determine whether RealTime performance could be improved for selected runs by varying the model-switching parameters.

If a need for a more effective model-switching algorithm is demonstrated, the calibration procedure for determining optimal parameters would be written in the C programming language and incorporated into the current code. The process could potentially include an inseason calibration capability whereby “outlier” years might be identified early and adjustments made inseason.

5.2 Adjustment of Data

Results of the 1998 utilization of a new smolt count adjustment formula based on research into the functional relationship between smolt survival and passage efficiencies at Lower Granite dam suggest a return to a previously-used formula for count adjustment be implemented. While the new formulation compares favorably to the old during the first half of the run (Table 10), the algorithm utilizing the old formula performed better during the last half which is more crucial for management decisions.

Continued monitoring of the effectiveness of RealTimes’s count adjustment formulas is recommended. Research into relationships between passage efficiencies at dams, river variables such as flow, and survival probabilities for different species (Skalski and Perez-Comas 1998, Connor, et al. 1998, for example) suggest the need to stay abreast of such findings in order to incorporate state-of-the-art information into Program RealTime’s formulas.

Potentially influential factors such as biological characteristics of runs tracked and forecasted should also be studied and potentially useful results applied to one or more of RealTime’s improvement/maintenance applications. In particular, this may have significant pay-off with runs like Redfish Lake Sockeye, which have displayed large size-at-release variability among smolts.

6.0 Conclusions and Summary

Good RealTime forecasting performance, comparable to previous years, was seen for the runs-at-large of Snake River yearling chinook, which was of normal size, and of Snake River steelhead, which was larger than average. Unusually large MADs (measuring large overpredictions by Program RealTime) observed in the first half of the 1998 outmigration of wild PIT-tagged yearling spring/summer chinook stocks and the run-at-large of wild subyearling fall chinook in the Snake River are primarily explained by uncharacteristically large, and in some cases as well, early outmigrations to Lower Granite Dam in 1998. The normal-sized run-at-large of yearling spring/summer chinook compared to PIT-tagged runs is not understood. High rates of yearling chinook PIT-detections are thought to be due to favorable parr overwintering conditions, as well as to better detection at the dam due to comparatively lower flows and spills or improvements in the PIT-detection system. A partial explanation for the large subyearling outmigration is that a large proportion of spring chinook inundated the (normally fall chinook) subyearling run and this was due to high spring chinook escapement in 1997. Another possible explanation is that flow-peaks during June and July account for the early migrations of a portion of normally residualizing fall chinook in the Snake River system.

Large overpredictions by Program RealTime occur during unusually large, early outmigrations because the forecaster-dynamics make a release-recapture model, one based on absolute counts, largely responsible for predictions at the beginning of a run, when fish first start to appear at the dam. Later in the outmigration, the algorithm provides for a model-switch which produces predictions by pattern-matching with historical-year distributions. The switching dynamic produces optimal performance during normal years, and can be potentially improved during unusual years like 1998 through research and development of an early-switching provision in an automatic in-season calibration process, which could potentially detect unusually large or small predictions at the beginning of a run and make early adjustments, thereby avoiding large initial over- or under-predictions.

A count-adjustment formula which compensates for PIT-tagged fish not detected at the dam, was revised and introduced in its new form this year. The effects of this new formula were determined to be qualitatively similar to the effects of the old one, which showed even larger overpredictions in the first half, but somewhat smaller predictions in the second half of the PIT-tagged yearling spring/summer chinook outmigrations, without exception. The implication of these results with respect to management is that a return to the old expansion method is warranted since managers are more interested in accurate predictions at the end of these runs than the beginning, because spill decisions depend on when the run is finished.

An Army Corps of Engineer (ACOE) experiment at Lower Granite Dam involving installation and experimentation with new dam components had the desirable effects of reducing turbine entrainment and increasing passage through the surface bypass collector but appeared to have little change in fish guidance efficiency, implying that there was no difference in the pattern of PIT-tag detections attributable to these conditions, and therefore no effect on Program RealTime performance.

The opportunity to check RealTime predictions based on FPC passage counts against predictions based on hydroacoustic counts made available by Battelle's Pacific Northwest Division during the ACOE experiment and LGD resulted in little difference between the predictions from the two data sources.

The influence of river variables (flow and temperature), of behavioral differences between species, of conditions at hydropower projects, and of other biological factors---on run-timing characteristics of outmigration stocks of salmonids will continue to be monitored, studied and applied in the forecasting enterprise.

7.0 Literature Cited

Achord, S., M.B. Eppard, E.E. Hockersmith, B.P. Sandford, G.M. Matthews. 1998. Monitoring the migrations of wild Snake River spring/summer chinook salmon smolts, 1997. National Marine Fisheries Service, Seattle, Washington. Annual Report 1997 (DOE/BP-18800-6) to Bonneville Power Administration, Project 9102800, Contract DE-A179-91BP18800. 86p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Achord, S., M.B. Eppard, E.E. Hockersmith, B.P. Sandford, G.M. Matthews. 1997. Monitoring the migrations of wild Snake River spring/summer chinook salmon smolts, annual report 1996. National Marine Fisheries Service, Seattle, Washington. Annual Report 1996 (DOE/BP-18800-5) to Bonneville Power Administration, Project 9102800, Contract DE-A179-91BP18800. 86p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Achord, S., M.B. Eppard, B.P. Sandford, G.M. Matthews. 1996. Monitoring the migrations of wild Snake River spring/summer chinook salmon smolts, 1995. National Marine Fisheries Service, Seattle, Washington. Annual Report 1995 (DOE/BP-18800-4) to Bonneville Power Administration, Project 9102800, Contract DE-A179-91BP18800. 194p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Achord, S., D.J. Kamikawa, B.P. Sandford, G.M. Matthews. 1995. Monitoring the migrations of wild Snake River spring/summer chinook salmon smolts, 1993. National Marine Fisheries Service, Seattle, Washington. Annual Report 1993 (DOE/BP-18800-2) to Bonneville Power Administration, Project 9102800, Contract DE-A179-91BP18800. 100p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Achord, S., G.M. Matthews, D.M. Marsh, B.P. Sandford, D.J. Kamikawa. 1994. Monitoring the migrations of wild Snake River spring/summer chinook salmon smolts, 1992. National Marine Fisheries Service, Seattle, Washington. Annual Report 1992 (DOE/BP-18800-1) to Bonneville Power Administration, Project 9102800, Contract DE-A179-91BP18800. 88p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Ashe, B. L., A. C. Miller, P. A. Kucera and M. L. Blenden. 1995. Spring Outmigration of Wild and Hatchery Chinook Salmon and Steelhead Trout Smolts from Imnaha River, March 1 - June 15, 1994. Nez Perce Tribe, Department of Fisheries Resources Management, Lapwai, Idaho. Technical Report (DOE/BP-38906-4) to Bonneville Power Administration, Project 87-127, Contract DE-FC79-88BP38906. 76 p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Beer, N., J.A. Hayes, R. Zabel, P. Shaw, J.J. Anderson. 1999. Evaluation of the 1998 Predictions of the Run-Timing of Wild Migrant Yearling Chinook in the Snake River Basin using CRiSP/RT. Report to Bonneville Power Administration, Project 89-108, Contract DE-B179-89BP02347.

Blenden, M. L., R. S. Osborne and P. A. Kucera. 1996. Spring outmigration of wild hatchery chinook salmon and steelhead trout smolts from the Imnaha River, Oregon, February 6-June 20, 1995. Nez Perce Tribe, Department of Fisheries Resources Management, Lapwai, Idaho. Annual Report 1995 (DOE/BP-38906-5a) to Bonneville Power Administration, Project 87-127, Contract DE-FC79-88BP38906. 74 p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Connor, W.P., H. Burge and R. Bugert. 1992. Migration timing of natural and hatchery fall chinook in the Salmon River Basin. Pages 46-56 in Passage and survival of juvenile chinook salmon migrating from the Snake River Basin. Proceedings of a technical workshop. Prepared by the Idaho Chapter of the American Fisheries Society, Idaho Water Resources Institute, University of Idaho Cooperative Fish and Wildlife Research Unit and the Western Division of the American Fisheries Society.

Connor, W.P., H.L. Burge and W.H. Miller. 1993. Rearing and emigration of naturally produced Snake River fall chinook salmon juveniles. Pages 81-116 *In* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing and migratory requirements of fall chinook in the Columbia River Basin. 1991 Annual Report to Bonneville Power Administration (DOE/BP-21708-1), Contract DEAI79-91BP21708, Portland, Oregon. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Connor, W.P., H.L. Burge and W.H. Miller. 1994a. Rearing and emigration of naturally produced Snake River fall chinook salmon juveniles. Pages 92-119 *In* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing and migratory requirements of fall chinook in the Columbia River Basin. 1992 Annual Report to Bonneville Power Administration (DOE/BP-21708-2), Contract DEAI79-91BP21708, Portland, Oregon. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Connor, W.P., H.L. Burge, D. Steele, C. Eaton and R. Bowen. 1994b. Rearing and emigration of naturally produced Snake River fall chinook salmon juveniles. Pages 41-73 *In* D.W. Rondorf and K.F. Tiffan, editors. Identification of the spawning, rearing and migratory requirements of fall chinook in the Columbia River Basin. 1993 Annual Report to Bonneville Power Administration (DOE/BP-21708-3), Contract DEAI79-91BP21708, Portland, Oregon. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Connor, W.P., H.L. Burge, R.D. Nelle, C. Eaton and R. Waitt. 1996. Rearing and emigration of naturally produced Snake River fall chinook salmon juveniles. Pages 44-63 *In* D.W. Rondorf and K.F.Tiffan, editors. Identification of the spawning, rearing and migratory requirements of fall chinook in the Columbia River Basin. 1994 Annual Report to Bonneville Power Administration (DOE/BP-21708-4), Contract DEAI79-91BP21708, Portland, Oregon. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Connor, W.P., T.C. Bjornn, H.L. Burge, A. Garcia, and D.W. Rondorf. 1997. Early life history and survival of natural subyearling fall chinook salmon in the Snake and Clearwater rivers in 1995. *In* D. Rondorf and K. Tiffan (editors), Identification of the spawing, rearing, and migratory requirements of fall chinook salmon in the Columbia River Basin, p. 18-47. Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, 112 p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Connor, W.P., H.L. Burge, D.H. Bennett. 1998. Detection of PIT-tagged Subyearling Chinook Salmon at a Snake River Dam: Implications for Summer Flow Augmentation. North American Journal of Fisheries Management :530-36.

Connor, W.P., and several co-authors. In preparation-b. Fall chinook salmon spawning habitat availability in the Snake River. A manuscript to be submitted to the North American Journal of Fisheries Management in 1999.

Fish Passage Center of the Columbia Basin Fish and Wildlife Authority. 1996. Fish Passage Center Weekly Report #99-23, (Available from Fish Passage Center of the Columbia Basin Fish and Wildlife Authority, 2501 SW First Avenue, Suite 230, Portland, OR 97201-4752.)

Garcia, A.P., and several co-authors. Fall chinook salmon spawning ground surveys in the Snake River. A manuscript to be submitted to the North American Journal of Fisheries Management in 1996.

Giorgi, A. E., and J. W. Schlechte. 1997. An evaluation of the effectiveness of flow augmentation in the Snake River, 1991-1995. Phase I Final Report (DOE/BP-24576-1) to Bonneville Power Administration 95-070-00, Contract DE-AC79-92BP24576. 47p. plus appendices. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Hayes, J. A., R. Zabel, P. Shaw, J. J. Anderson. 1996. Evaluation of the 1996 predictions of the run-timing of wild migrant yearling chinook at multiple locations in the Snake and Columbia River Basins using CRiSP/RealTime. Center for Quantitative Science, School of Fisheries, University of Washington, Seattle, Washington. Technical Report to Bonneville Power Administration Project 89-108, Contract DE-BI79-89BP02347. 74 p.

Johnson, R.L., S.M. Anglea, S.L. Blanton, M.A. Simmons, R.A. Moursand, G.E. Johnson, E.A. Kudera, J. Thomas, J.R. Skalski. 1999. Hydroacoustic Evaluation of Fish Passage and Behaviour at Lower Granite Dam in Spring 1998. Final Report to U.S. Army Corps of Engineers, Walla Walla District PNWD-2448, Contract DACW68-96-D-0002.

Keefe, M. L., D. J. Anderson, R. W. Carmichael and B. C. Jonasson. 1996. Early life history study of Grande Ronde River Basin chinook salmon. Oregon Department of Fish and Wildlife, Fish Research Project. 1995 Annual Report (D147 DOE/BP-33299-1B) to the Bonneville Power Administration, Portland, Oregon, Project 92-026-04, Contract 94BI33299. 39p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Marshall, A., W.P. Connor, and several co-authors. Stock and race identification of subyearling chinook salmon in the Snake River. Submitted to Transactions of the American Fisheries Society in 1998.

Nelson, W.R., L.K. Freidenburg and D.W. Rondorf. Accepted. Swimming behavior and performance of emigrating subyearling chinook salmon. Transactions of the American Fisheries Society.

OWICU. 1996. Memorandum dated June 3, 1996, prepared by technical staffs of the Columbia River salmon management agencies to Implementation Team: Review of Fall Chinook Juvenile Migration Data. 19 p.

Prentice, E.F., T.A. Flagg, and C.S. McCutcheon. 1990a. Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. Am. Fish. Soc. Symp. 7:317-322.

Prentice, E.F., T.A. Flagg, C.S. McCutcheon, and D.F. Brastow. 1990b. PIT-tag monitoring systems for hydroelectric dams and fish hatcheries. Am. Fish. Soc. Symp. 7:323-334.

Prentice, E.F., T.A. Flagg, C.S. McCutcheon, D.F. Brastow, and D.C. Cross. 1990c. Equipment, methods, and an automated data-entry station for PIT tagging. Am. Fish. Soc. Symp. 7:335-340.

Rondorf, D.W., and W.H. Miller, editors. 1993. Identification of the spawning, rearing and migratory requirements of fall chinook salmon in the Columbia River basin. 1991 Annual Report to Bonneville Power Administration (DOE/BP-21708-1), Contract DEAI79-91BP21708, Portland, Oregon. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Rondorf, D.W., and W.H. Miller, editors. 1994a. Identification of the spawning, rearing and migratory requirements of fall chinook salmon in the Columbia River basin. 1992 Annual Report to Bonneville Power Administration (DOE/BP-21708-2), Contract DEAI79-91BP21708, Portland, Oregon. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Rondorf, D.W., and K.F. Tiffan, editors. 1994b. Identification of the spawning, rearing and migratory requirements of fall chinook salmon in the Columbia River basin. 1993 Annual Report to Bonneville Power Administration (DOE/BP-21708-3), Contract DEAI79-91BP21708, Portland, Oregon. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Rondorf, D.W., and K.F. Tiffan, editors. 1996. Identification of the spawning, rearing and migratory requirements of fall chinook salmon in the Columbia River basin. 1994 Annual Report to Bonneville Power Administration (DOE/BP-21708-4), Contract DEAI79-91BP21708, Portland, Oregon. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Smith, S.G., J.R. Skalski, A.E. Giorgi. 1993. Statistical Evaluation of Travel itme Estimation based on Data from Freeze-Branded Chinook Salmon on the Snake River, 1982-1990. Technical Report (DOE/BP-35885-4) to Bonneville Power Administration, Portland, Oregon, Project 91-051, Contract DE-B179-91BP35885. 113 p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Smith, S. G., W. D. Muir, E. E. Hokersmith, M. B. Eppard, and W. P. Connor. 1997. Passage survival of natural and hatchery subyearling fall chinook salmon to Lower Granite, Little Goose, and Lower Monumental Dams. Pages 1-65 *In* J. G. Williams and T. C. Bjornn, editors. Fall chinook salmon survival and supplementation studies in the Snake and Lower Columbia River Reservoirs, 1995. Annual Report (DOE-BP-10891-4) to Bonneville Power Administration, Portland, Oregon, Project 93-029, Contract 93AI10891 and the U.S. Army Corps of Engineers, Contract E86950141. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Skalski, J. R., G. Tartakovsky, S. G. Smith and P. Westhagen. 1994. Pre-1994 Season Projection of Run-Timing Capabilities Using PIT-tag Databases. Center for Quantitative Science, School of Fisheries, University of Washington, Seattle, Washington. Technical Report (DOE/BP-35885-7) to Bonneville Power Administration, Portland, Oregon, Project 91-051, Contract DE-BI79-87BP35885. 67 p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Skalski, J.R. and J. Perez-Comas. 1998. Using steelhead and chinook salmon PIT-tag recapture probabilities to Estimate Fish Guidance Efficiency and Spill Effectiveness at Lower Granite Dam. February 1998 draft of Report to Army Corps of Engineers, Walla Walla, Contract No. DACW68-96-C0018.

Tiffan, K.F., and several co-authors. In preparation-a. Morphological differences between emigrating juvenile spring and fall chinook salmon in the Snake River. A manuscript to be submitted to the Transactions of the American Fisheries Society in 1999.

Tiffan, K.F., and several co-authors. In review-b. Marking subyearling chinook salmon to estimate adult contribution in the Columbia River. A manuscript submitted to the North American Journal of Fisheries Management.

Townsend, R. L., P. Westhagen, D. Yasuda and J. R. Skalski. 1995. Evaluation of the 1994 Predictions of the Run-Timing of Wild Migrant Yearling Chinook in the Snake River Basin. Center for Quantitative Science, School of Fisheries, University of Washington, Seattle, Washington. Technical Report (DOE/BP-35885-8) to Bonneville Power Administration, Portland, Oregon, Project 91-051, Contract DE-BI79-87BP35885. 93 p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Townsend, R. L., P. Westhagen, D. Yasuda, J. R. Skalski, and K. Ryding. 1996. Evaluation of the 1995 Predictions of the Run-Timing of Wild Migrant Yearling Chinook in the Snake River Basin using Program RealTime. Center for Quantitative Science, School of Fisheries, University of Washington, Seattle, Washington. Technical Report (DOE/BP-35885-9) to Bonneville Power Administration, Portland, Oregon, Project 91-051, Contract DE-BI79-87BP35885. 64 p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Townsend, R. L.,D. Yasuda, and J. R. Skalski. 1997. Evaluation of the 1996 Predictions of the Run-Timing of Wild Migrant Spring/Summer Yearling Chinook in the Snake River Basin Using Program RealTime. School of Fisheries, University of Washington, Seattle, Washington. Technical Report (DOE/BP-91572-1) to Bonneville Power Administration, Portland, Oregon, Project 91-051, Contract 96BI91572. 30 p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Townsend, R. L., J. R. Skalski, and D. Yasuda. 1998a. Evaluation of the 1995 Predictions of the Run-Timing of Wild Migrant Subyearling Chinook in the Snake River Basin Using Program RealTime. School of Fisheries, University of Washington, Seattle, Washington. Technical Report (accepted) to Bonneville Power Administration, Portland, Oregon, Project 91-051, Contract DE-BI79-87BP35885. 31 p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

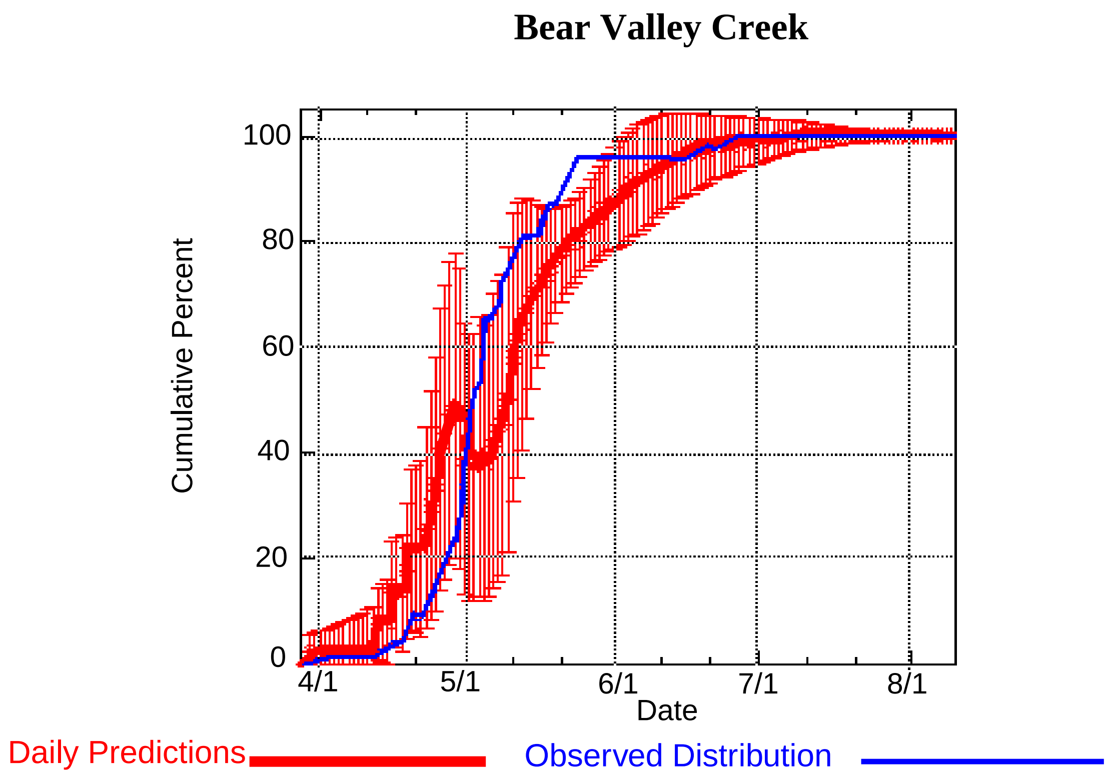
Townsend, R. L., J. R. Skalski, and D. Yasuda. 1998b. Evaluation of the 1996 Predictions of the Run-Timing of Wild Migrant Subyearling Chinook in the Snake River Basin Using Program RealTime. School of Fisheries, University of Washington, Seattle, Washington. Technical Report (accepted) to Bonneville Power Administration, Portland, Oregon, Project 91-051, Contract DE-BI79-87BP35885. 21 p. (Available from Bonneville Power Administration, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR. 97283-3621.)

Wilson, J. W., A. E. Giorgi, and L. C. Stuehrenberg. 1991. A method for estimating spill effectiveness for passing juvenile salmon and its application at Lower Granite Dam on the Snake River. Can. J. Fish. Aquat. Sci. 48:1872-1876.

Appendix A

<u>Performance Plots for the 1998 Out-migration Season</u>

Figure A1: Bear Valley Creek and Catherine Creek Daily Predictions.



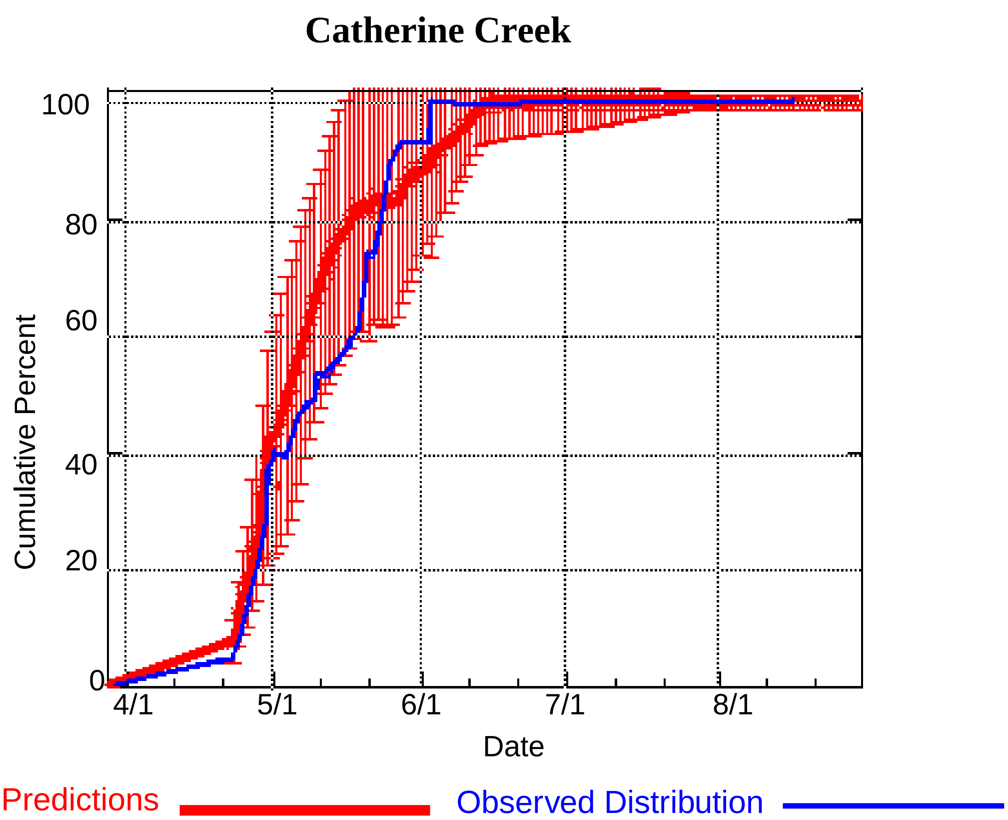
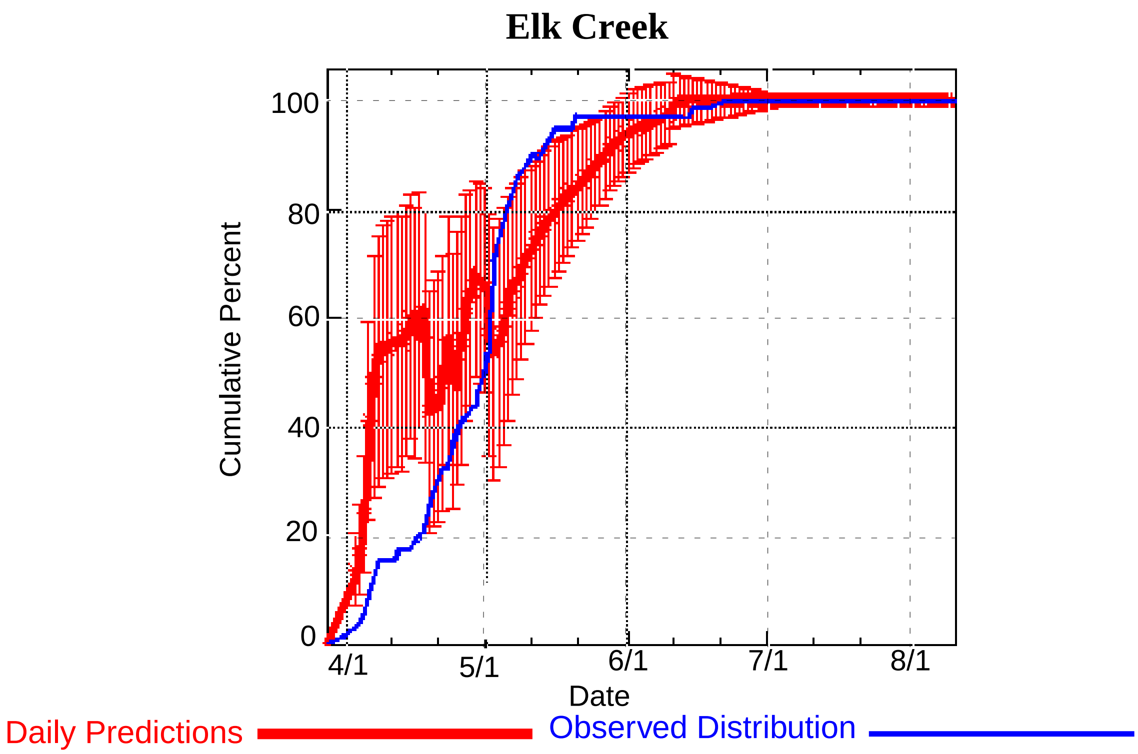


Figure A2: Elk Creek and Imnaha River Daily Predictions.



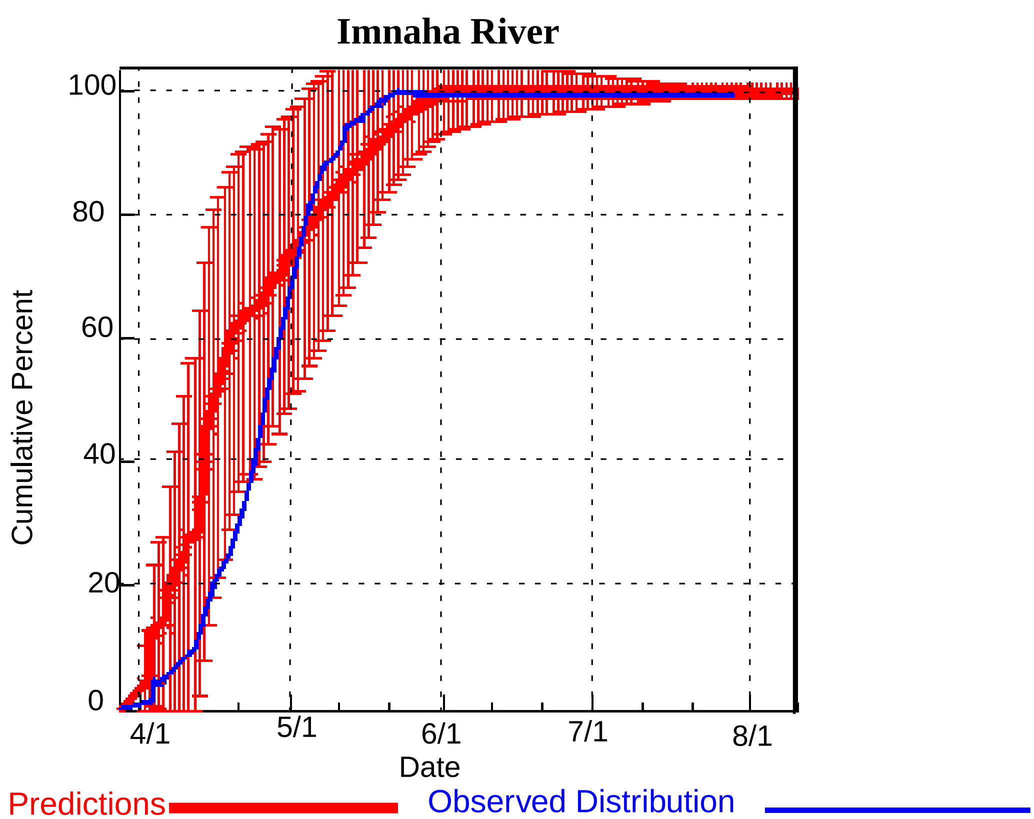
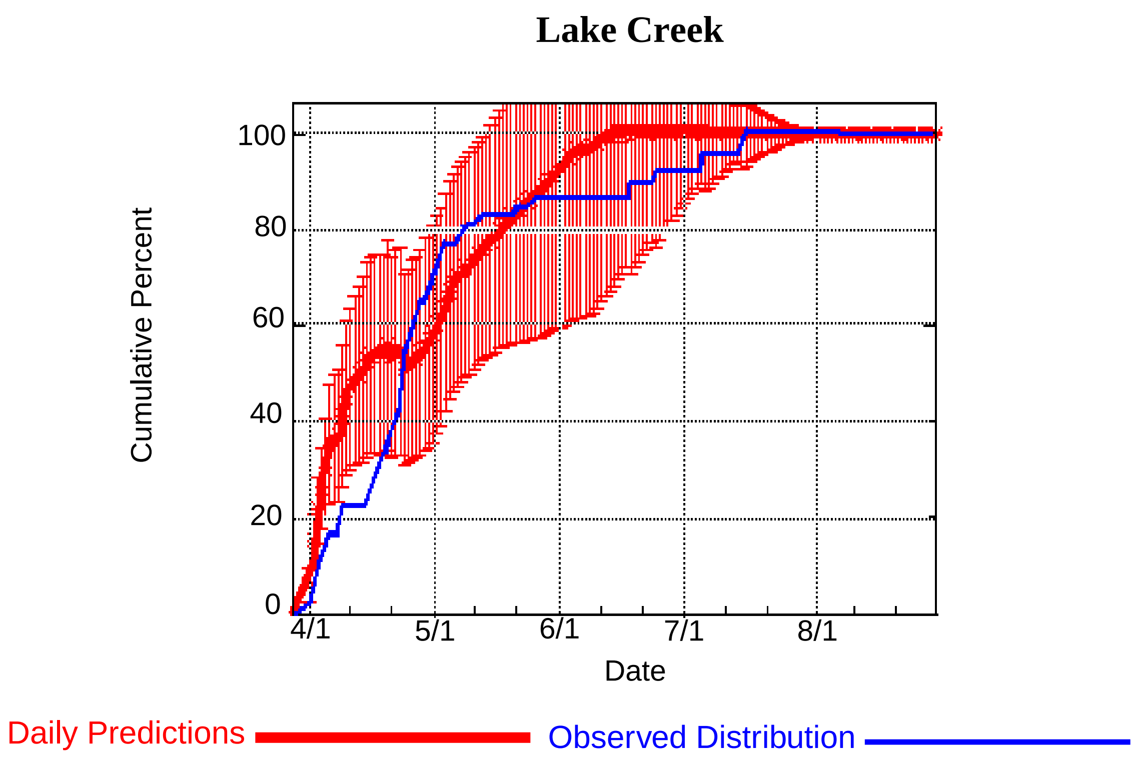


Figure A3: Lake Creek and Minam River Daily Predictions



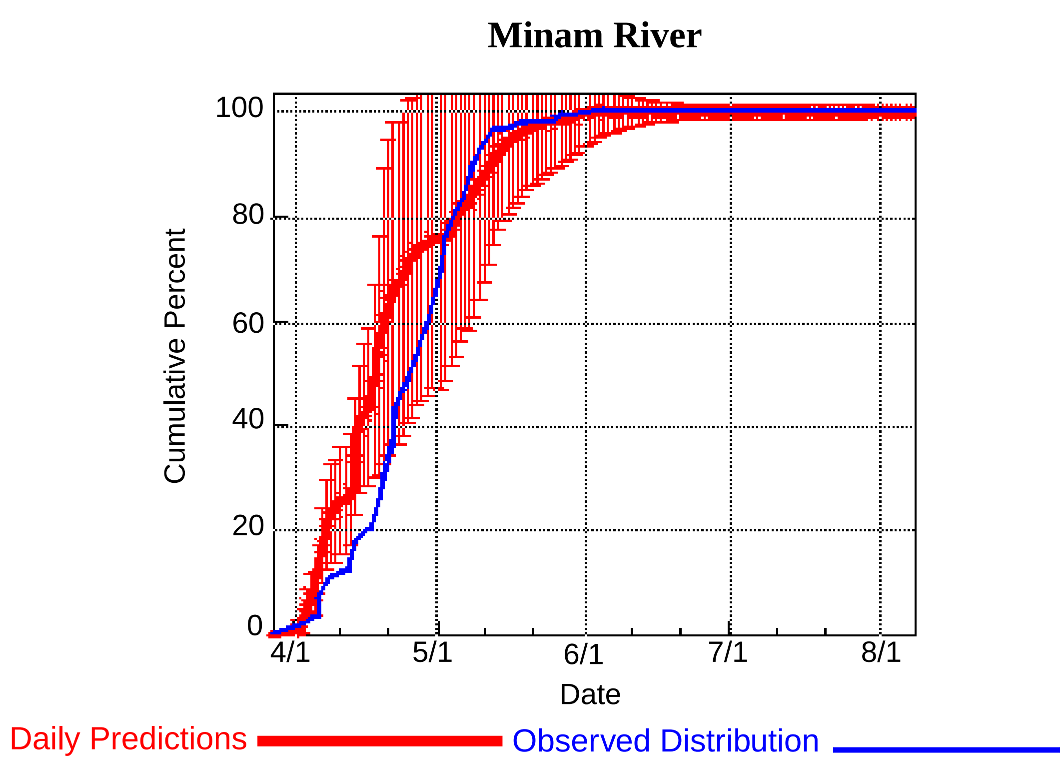
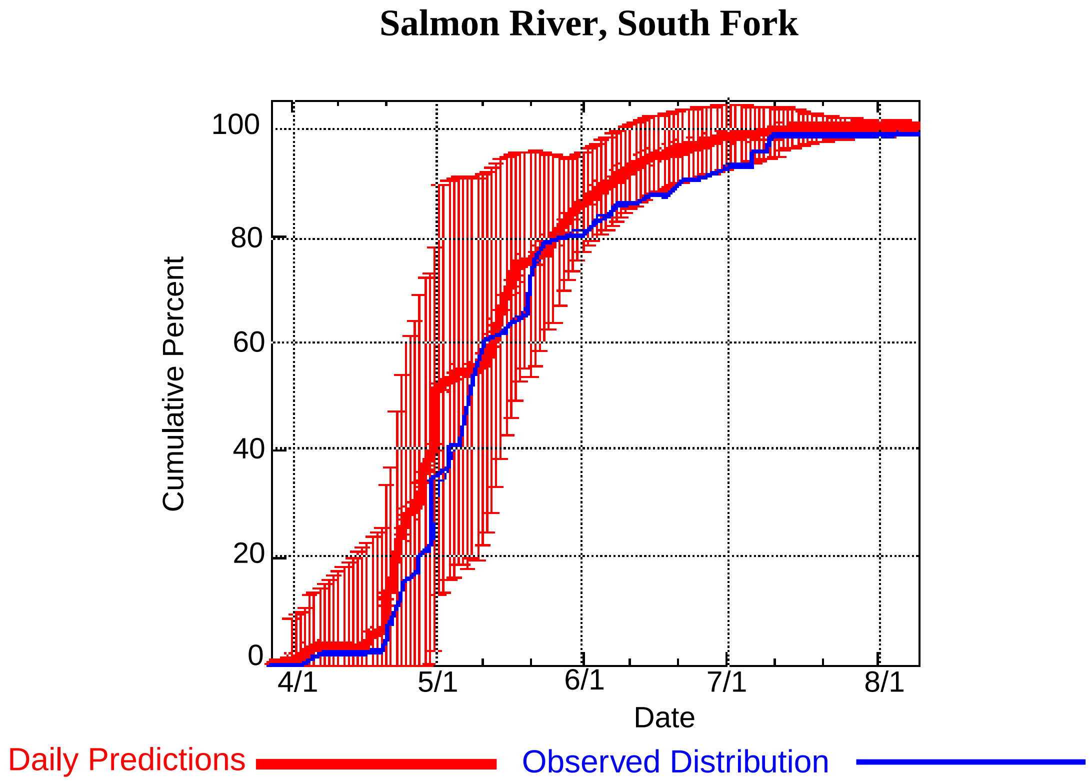


Figure A4: Salmon River, South Fork and Secesh River Daily Predictions.



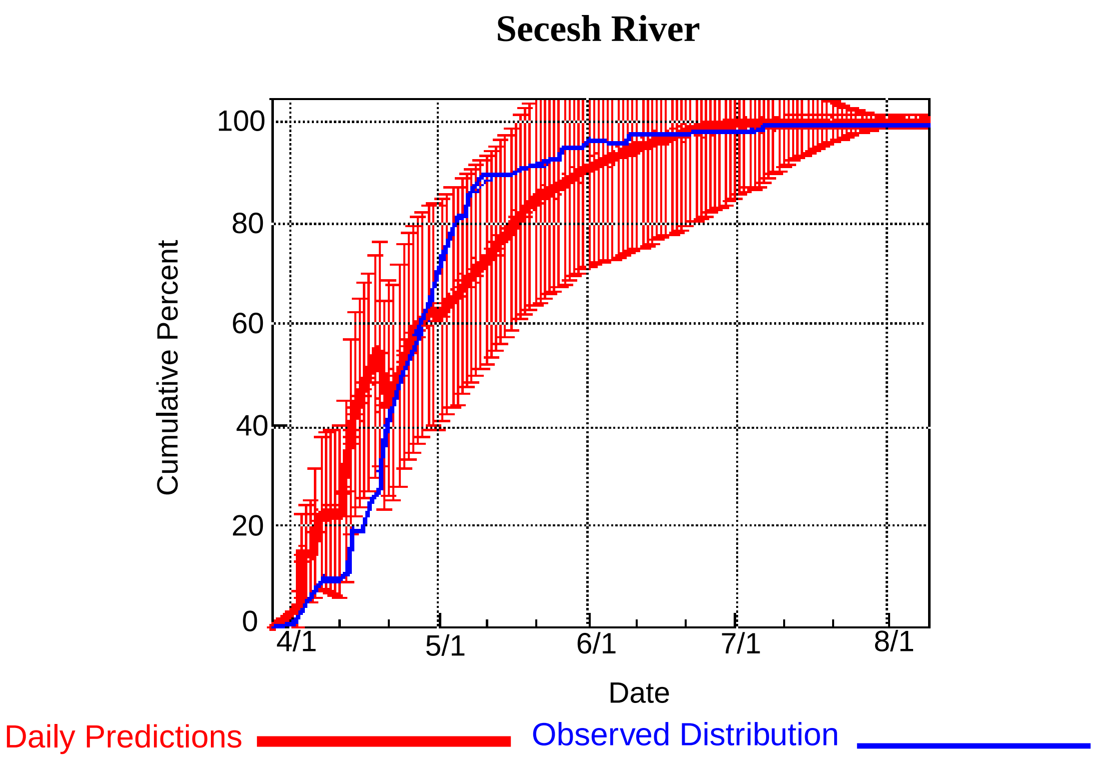
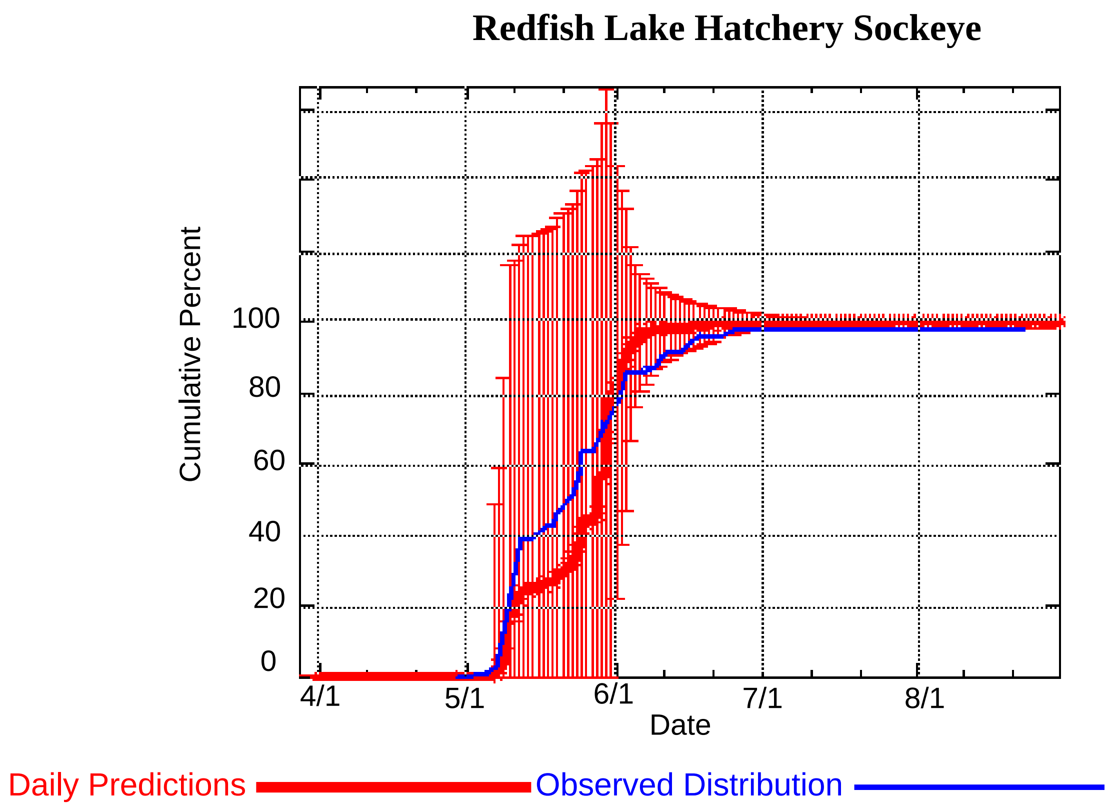


Figure A5: Redfish Lake and Subyearling Run-of-River Daily Predictions.



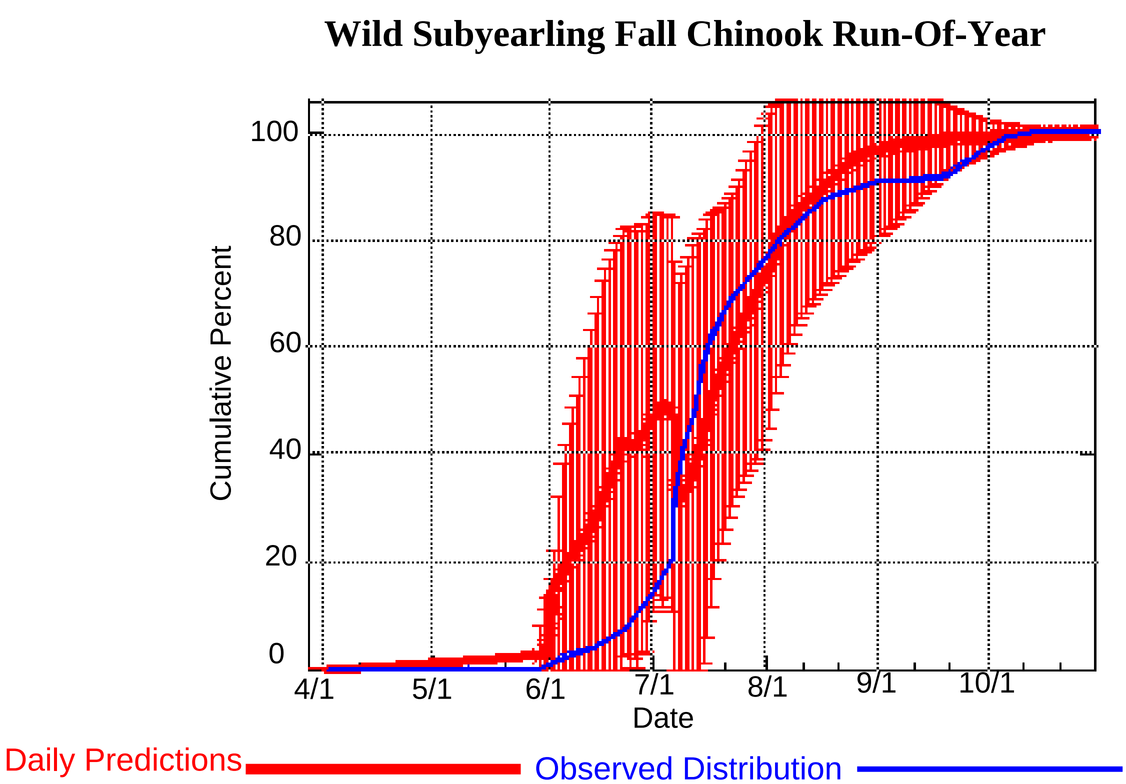
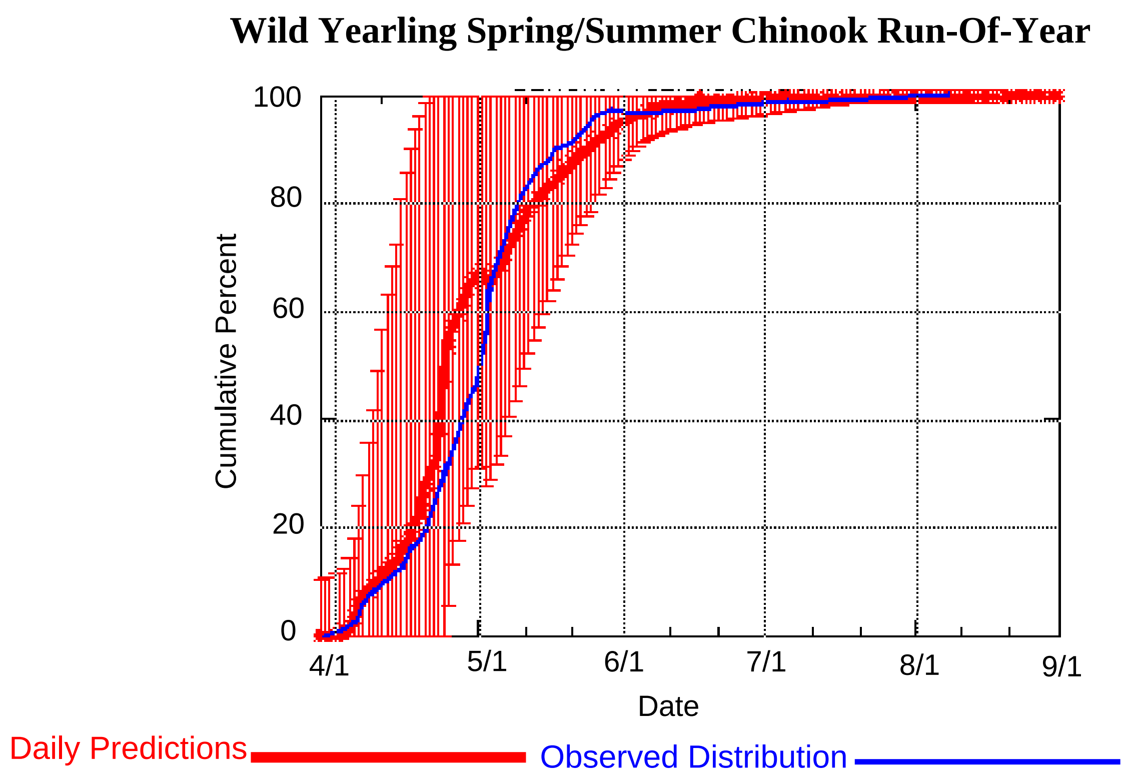
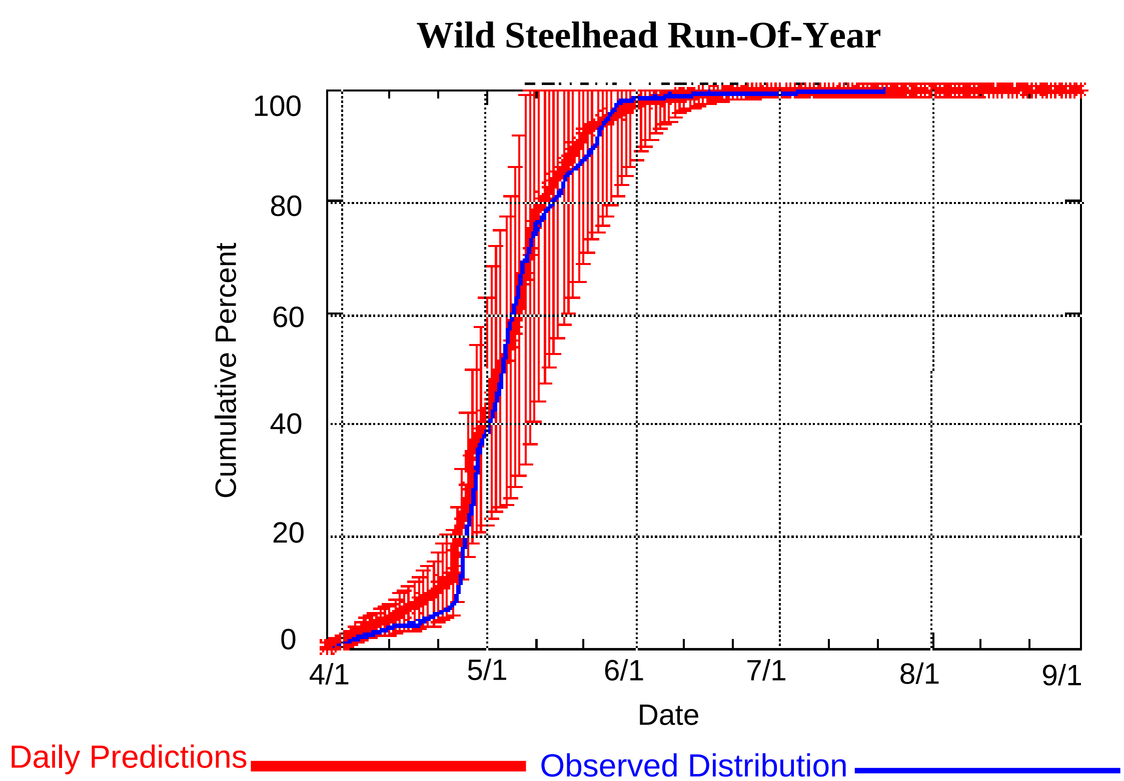


Figure A6: Wild Yearling Chinook and Steelhead Run-of-River Daily Predictions.





Appendix B

Historical timing plots and dates of passage at Lower Granite Dam (from PIT-tag data) for the individual wild yearling chinook release sites tracked by program RealTime during the 1998 outmigration season, for the subyearling chinook, yearling chinook, and steelhead runs-of-the-year, and for Redfish Lake hatchery sockeye.

Figure B1: Historical Bear Valley Creek outmigration distribution at Lower Granite Dam.

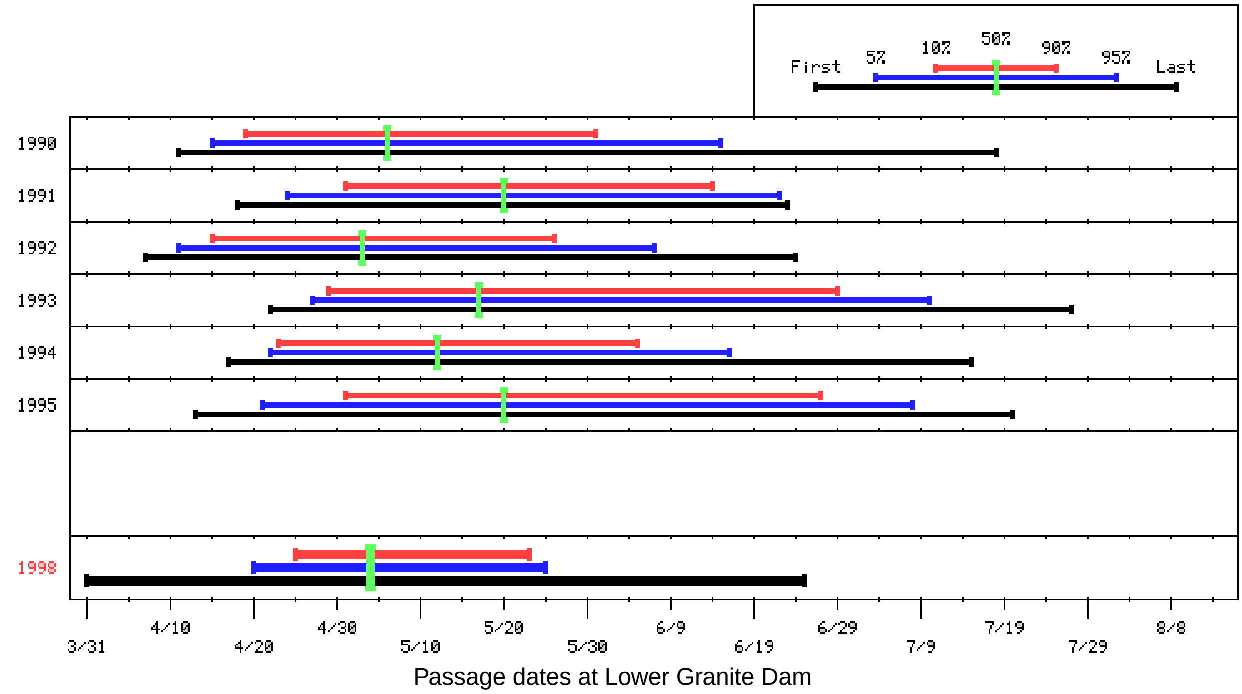


Table B1: Historical Bear Valley Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1990	4/11	4/15	4/19	5/06	5/31	6/15	7/18	43	1557	91	195.9	12.6
1991	4/14	4/24	5/01	5/20	6/14	6/22	6/23	45	353	44	87.8	24.9
1992	4/6	4/8	4/10	4/21	5/3	5/7	5/21	42	1044	69	185.6	17.8
1993	4/15	4/22	4/25	5/15	5/29	6/3	6/23	62	1017	67	183.8	18.1
1994	4/2	4/15	4/18	4/23	5/12	5/31	8/11	44	860	85	286.6	33.3
1995	4/10	4/11	4/14	5/9	6/3	6/4	7/7	58	1460	74	223.4	15.3
1998	3/31	4/20	4/25	5/04	5/23	5/25	6/25	29	427	59	212.9	49.9

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B2: Historical Catherine Creek outmigration distribution at Lower Granite Dam.

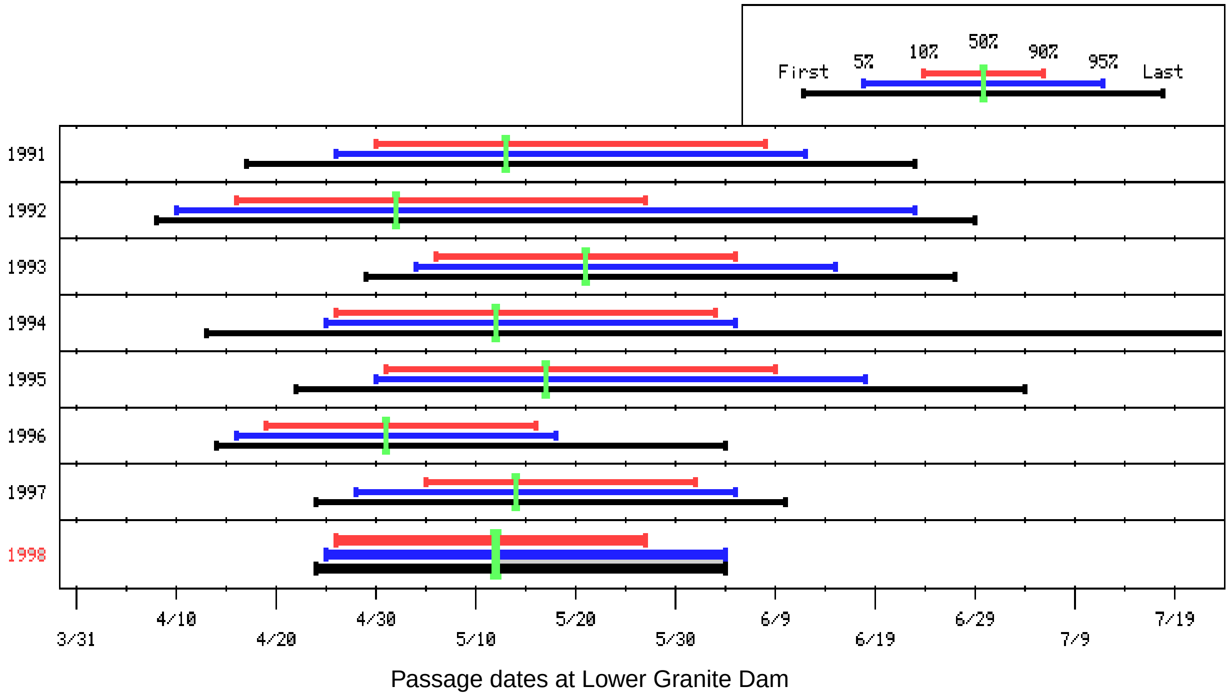


Table B2: Historical Catherine Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1991	4/17	4/26	5/1	5/14	6/8	6/12	6/23	39	1014	77	77.8	7.7
1992	4/8	4/15	4/16	5/1	5/21	5/28	6/29	36	940	67	67.0	7.1
1993	4/29	5/4	5/6	5/18	6/2	6/10	6/27	28	1108	102	158.2	14.3
1994	4/13	4/25	4/26	5/12	5/30	6/3	7/26	35	1000	76	110.5	11.0
1995	4/22	4/30	5/1	5/13	6/6	6/16	7/4	37	2061	202	268.1	13.0
1996	4/14	4/15	4/18	4/30	5/17	5/18	6/4	30	1682	116	261.7	15.6
1997	4/24	4/28	5/05	5/14	6/01	6/05	6/10	28	585	51	120.2	20.6
1998	4/24	4/25	4/26	5/12	5/27	6/04	6/04	32	495	43	155.2	31.4

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B3: Historical Elk Creek outmigration distribution at Lower Granite Dam.

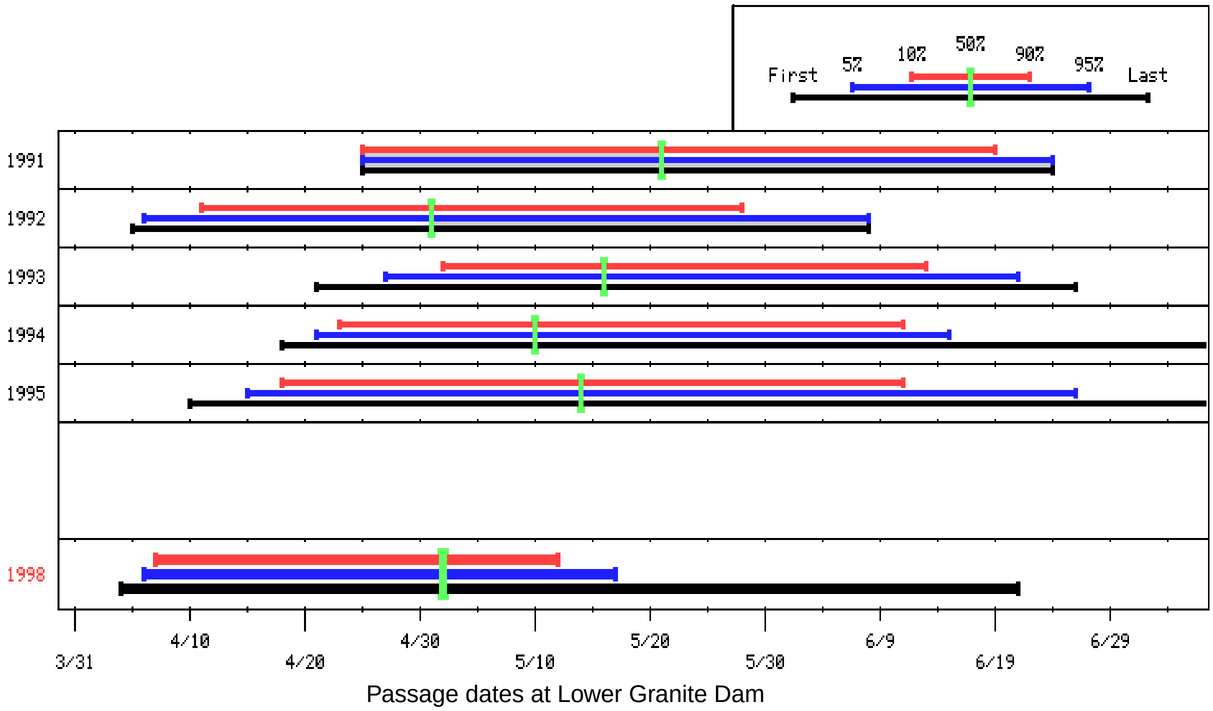


Table B3: Historical Elk Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1991	4/25	4/25	4/25	5/21	6/19	6/24	6/24	56	248	32	66.3	26.7
1992	4/05	4/06	4/11	5/01	5/28	6/08	6/08	48	462	36	96.9	21.0
1993	4/21	4/27	5/02	5/16	6/13	6/21	6/26	43	628	42	107.5	17.1
1994	4/18	4/21	4/23	5/10	6/11	6/15	7/09	50	999	76	234.0	23.4
1995	4/11	4/15	4/18	5/14	6/11	6/26	7/09	55	1514	75	215.7	14.3
1998	4/04	4/06	4/07	5/02	5/12	5/17	6/21	36	246	57	204.5	83.1

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B4: Historical Imnaha River outmigration distribution at Lower Granite Dam.

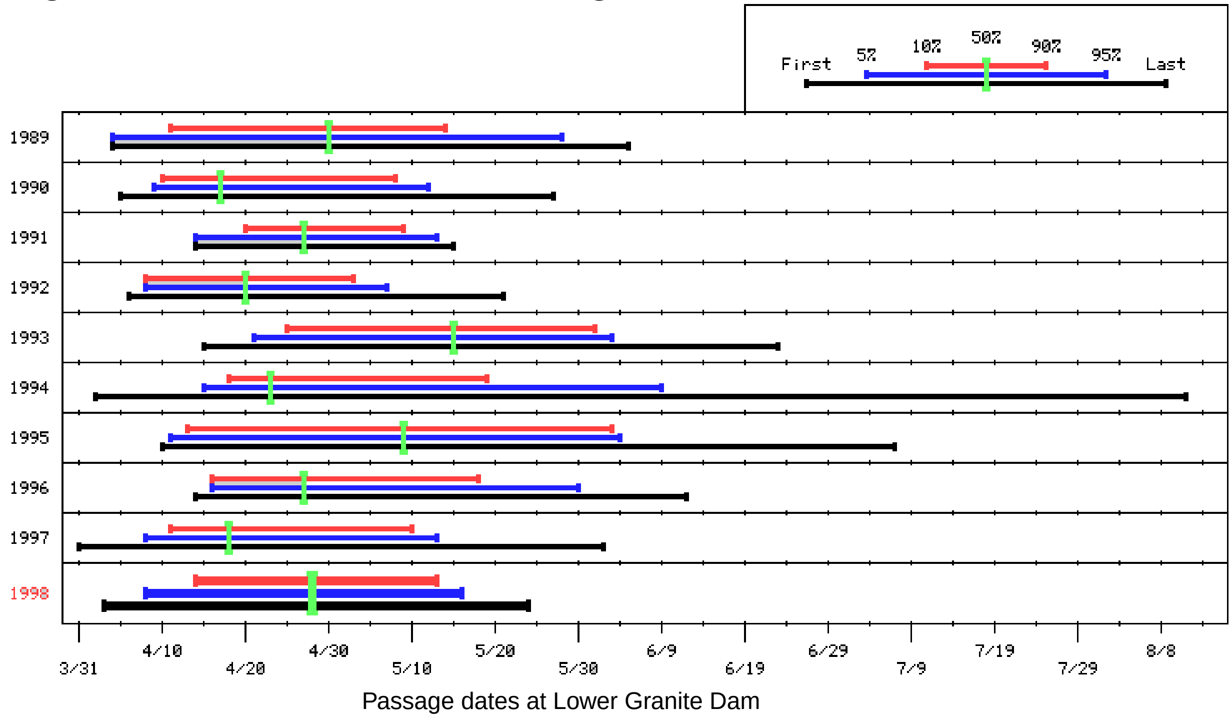


Table B4: Historical Imnaha River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/4	4/4	4/11	4/30	5/11	5/27	6/5	31	1213	73	73.0	6.0
1990	4/5	4/9	4/10	4/18	5/8	5/12	5/27	29	2005	161	161.0	8.0
1991	4/14	4/14	4/20	5/1	5/13	5/15	5/15	24	334	18	18.0	5.4
1992	4/6	4/8	4/10	4/21	5/3	5/7	5/21	24	759	73	73.0	9.6
1993	4/15	4/22	4/25	5/15	5/29	6/3	6/23	35	1003	63	88.3	8.8
1994	4/2	4/15	4/18	4/23	5/12	5/31	8/11	25	1753	205	218.2	12.4
1995	4/10	4/11	4/14	5/9	6/3	6/4	7/7	51	999	40	50.9	5.1
1996	4/14	4/15	4/16	4/26	5/18	6/1	6/12	33	997	97	233.5	23.4
1997	3/31	4/08	4/11	4/20	5/11	5/14	6/02	31	1017	98	191.1	18.8
1998	4/03	4/08	4/14	4/28	5/13	5/16	5/24	30	1010	159	579.1	57.3

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B5: Historical Lake Creek outmigration distribution at Lower Granite Dam.

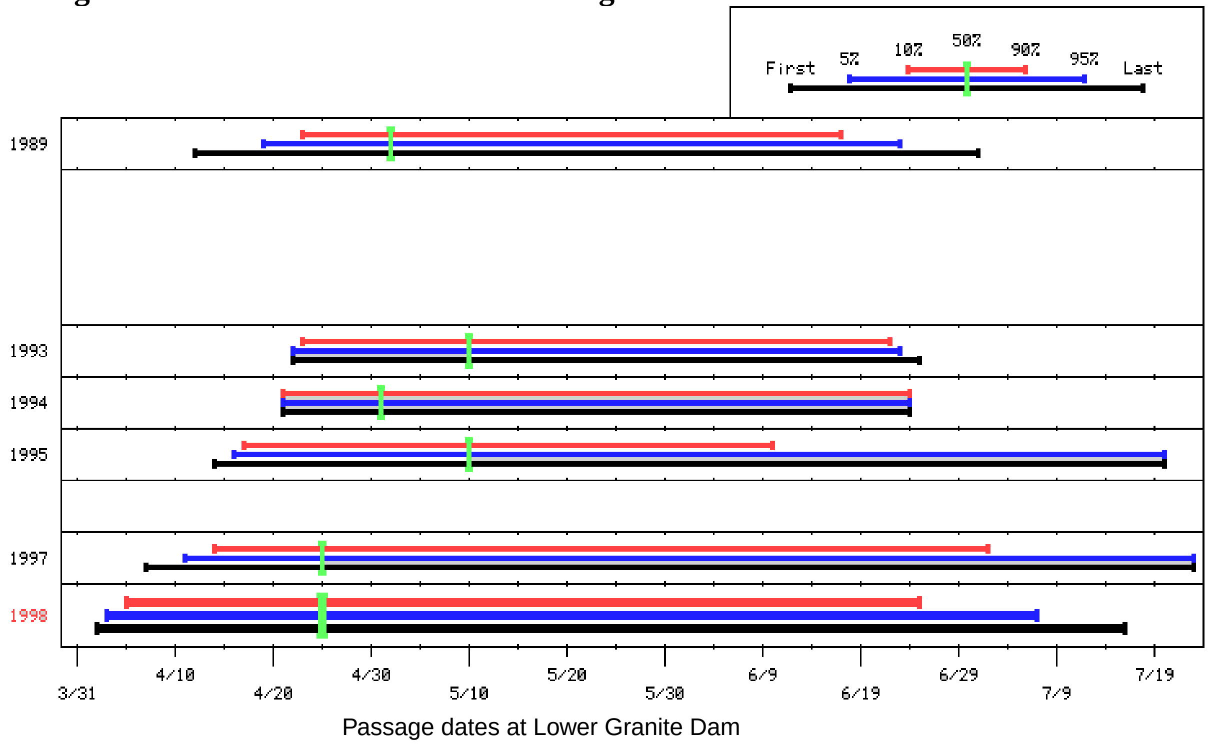


Table B5: Historical Lake Creek outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/12	4/19	4/23	5/02	6/16	6/17	7/01	55	660	51	51.0	7.7
1993	4/22	4/22	4/24	5/14	6/21	6/23	6/25	59	255	27	31.1	12.2
1994	4/21	4/21	4/21	4/28	5/19	6/24	6/24	29	252	17	19.8	7.9
1995	4/14	4/16	4/17	5/10	6/07	6/10	7/20	52	406	25	33.2	8.2
1997	4/07	4/11	4/14	4/25	6/22	7/02	7/23	70	400	21	40.8	10.2
1998	4/02	4/03	4/05	4/25	6/25	7/07	7/16	82	418	48	174.1	41.7

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B6: Historical Minam River outmigration distribution at Lower Granite Dam.

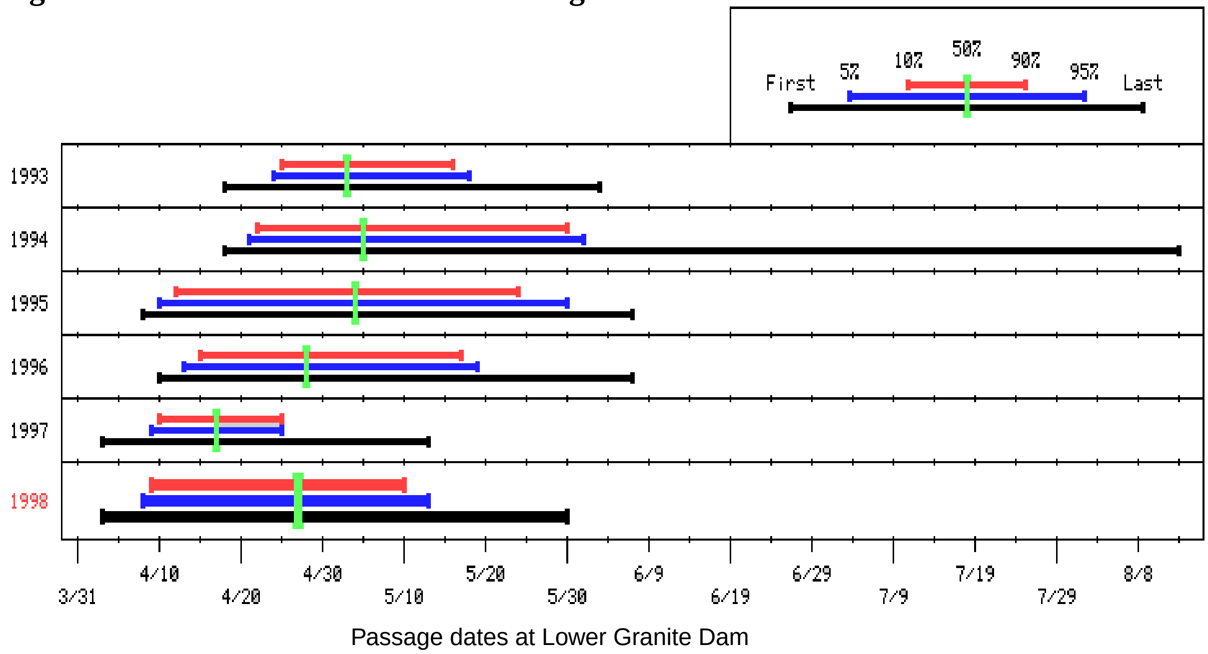


Table B6: Historical Minam River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1993	4/18	4/24	4/25	5/6	5/16	5/18	6/3	22	1003	105	125.5	12.5
1994	4/18	4/21	4/22	5/1	5/18	5/31	8/13	39	1005	112	133.3	13.3
1995	4/8	4/10	4/12	5/4	5/24	6/6	6/7	43	998	70	89.3	9.0
1996	4/10	4/13	4/14	4/25	5/18	5/19	6/7	33	998	68	164.9	16.5
1997	4/03	4/09	4/11	4/19	4/25	4/25	5/13	16	589	49	92.4	15.7
1998	4/04	4/08	4/09	4/27	5/10	5/13	5/30	32	998	123	454.3	45.5

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B7: Historical Salmon River (South Fork) outmigration distribution at Lower Granite Dam.

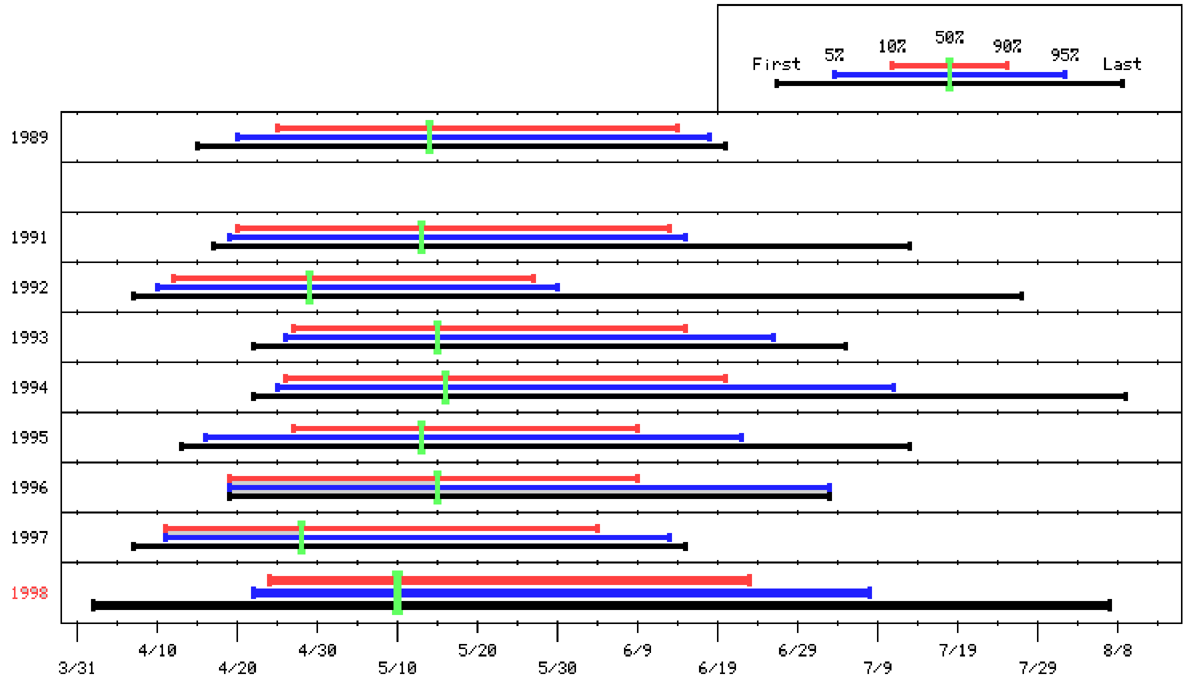


Table B7: Historical Salmon River (South Fork) outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/15	4/20	4/25	5/12	6/12	6/15	6/20	51	2226	84	84.0	3.8
1991	4/17	4/19	4/20	5/17	6/10	6/14	7/13	55	992	98	98.8	10.0
1992	4/7	4/10	4/14	4/29	5/27	5/28	7/27	46	1031	81	81.0	7.9
1993	4/22	4/26	4/28	5/16	5/29	6/17	7/5	50	1718	173	262.0	15.2
1994	4/22	4/24	4/26	5/15	6/4	6/25	8/9	56	5951	450	645.1	10.8
1995	4/13	4/16	4/24	5/11	6/10	6/10	7/13	44	1574	78	105.2	7.0
1996	4/19	4/19	4/19	5/15	6/9	6/9	7/3	52	700	16	37.2	5.3
1997	4/07	4/11	4/13	4/28	6/12	6/13	6/15	55	700	36	78.9	11.3
1998	4/02	4/22	4/24	5/10	6/23	7/08	8/07	61	1007	83	299.2	29.7

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B8: Historical Secesh River outmigration distribution at Lower Granite Dam.

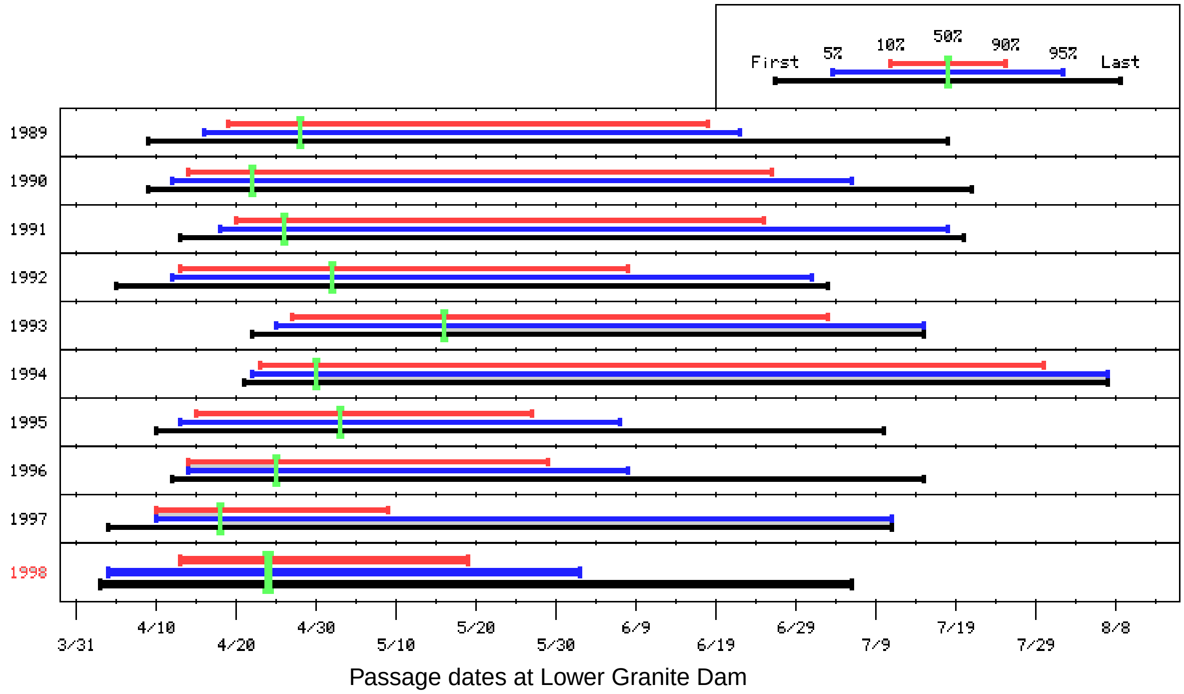


Table B8: Historical Secesh River outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1989	4/09	4/16	4/19	4/27	6/09	6/19	7/18	61	1940	190	190.0	9.8
1990	4/09	4/12	4/14	4/22	6/13	6/27	7/21	74	2176	157	157.0	7.2
1991	4/13	4/18	4/20	4/28	6/14	6/27	7/20	67	1018	71	72.3	7.1
1992	4/05	4/11	4/13	4/29	6/04	6/08	7/03	57	1013	40	40.0	3.9
1993	4/22	4/25	4/27	5/16	6/16	7/03	7/15	68	327	30	37.0	11.3
1994	4/21	4/22	4/23	4/27	7/11	7/30	8/07	99	422	32	33.0	7.8
1995	4/10	4/13	4/15	5/03	5/25	6/06	7/10	43	1551	90	112.4	7.2
1996	4/12	4/12	4/14	4/25	5/28	6/08	7/15	46	571	26	70.0	12.3
1997	4/04	4/10	4/10	4/19	5/04	5/31	7/11	30	260	34	62.7	24.1
1998	4/03	4/04	4/13	4/24	5/19	6/02	7/06	37	588	74	269.3	45.8

(1) Parr PIT-tagged and released during the summer of the year prior to detection year.
(2) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of yearling Age 1 chinook smolts at Lower Granite Dam.

Figure B9. Timing plots of passage dates (0%, 10%, 50%, 90% and 100%) at Lower Granite Dam for age 1+ hatchery-reared sockeye salmon released from Redfish Lake.

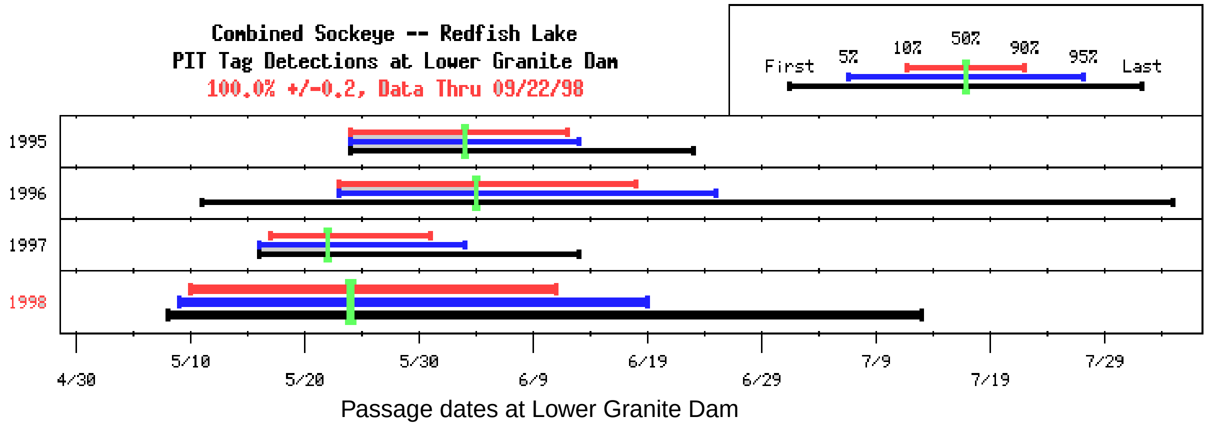


Table B9: Historical Redfish Lake outmigration timing characteristics.

Detection Year	Detection Dates							Duration Middle 80% (days)	Parr Released (1)	LGR PIT Detections (2)	Adjusted LGR PIT Detections (3)	% (3)/(1) x 100
	First	5%	10%	50%	90%	95%	Last					
1995	5/24	5/24	5/24	6/03	6/12	6/13	6/23	20	2728	20	26.6	1.0
1996	5/11	5/23	5/23	6/04	6/18	6/25	8/04	27	4246	160	377.8	8.9
1997	5/16	5/16	5/17	5/22	5/31	6/03	6/13	15	1931	53	131.2	6.8
1998	5/08	5/09	5/10	5/24	6/11	6/14	7/13	33	4692	71	145.6	3.1

1) Age 0+ juvenile sockeye PIT-tagged and released during the summer/fall of the year prior to detection year.
(2) PIT detections of yearling Age 1+ sockeye salmon at Lower Granite Dam.
(3) Spill-adjusted (Appendix C) PIT detections of Age 1+ sockeye smolts at Lower Granite Dam.

Figure B10: Historical Run of Year subyearling outmigration distribution at Lower Granite Dam.

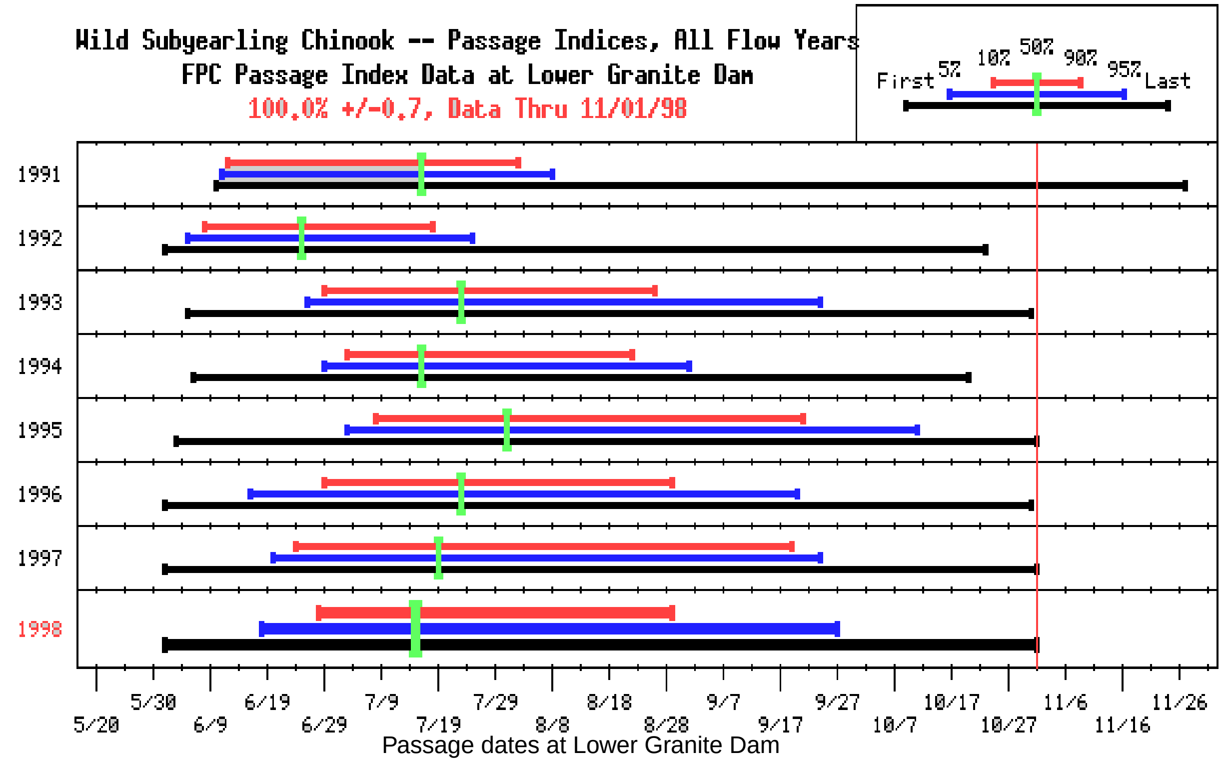


Table B10: Historical wild subyearling chinook outmigration timing characteristics at Lower Granite Dam using historical passage indices for 1991-98.

Detection Year	Passage Dates (1)							Duration Middle 80% (days)	6/1 - last LGR Pass. Index (2)	Total LGR Pass. Index (3)	BOS Date (4)	First Detection Date (5)	EOS Date (6)
	First	5%	10%	50%	90%	95%	Last						
1991	6/10	6/11	6/12	7/16	8/02	8/08	11/27	52	13672	13874	3/28	4/14	11/27
1992	6/01	6/05	6/08	6/25	7/18	7/25	10/23	41	5744	5966	4/02	4/29	10/31
1993	6/05	6/26	6/29	7/23	8/26	9/24	10/31	59	16620	16908	4/15	5/11	10/31
1994	6/06	6/29	7/03	7/16	8/22	9/01	10/20	51	6765	6812	4/02	5/23	11/01
1995	6/03	7/03	7/08	7/31	9/21	10/11	11/01	76	26046	26645	3/29	4/10	11/01
1996	6/1	6/16	6/29	7/23	8/29	9/20	10/31	62	17548	18498	3/26	4/04	11/01
1997	6/1	6/20	6/24	7/19	9/19	9/24	11/01	88	17561	19128	3/27	4/06	10/31
1998	6/1	6/18	6/28	7/15	8/29	9/27	11/1	63	82499	88361	3/27	3/28	11/5

(1) Percentage passage dates based on wild subyearling passage indices for period 6/01 to last data. First is the first subyearling starting at 6/01.
(2) LGR FPCWild Subyearling Chinook Passage Indices, All Flow Years yearly totals for period 6/01 to last data.
(3) LGR FPC Wild Subyearling Chinook Passage Indices, All Flow Years yearly totals for the entire SMP sampling period.
(4) Beginning of SMP sampling at Lower Granite Dam.
(5) First subyearling chinook of the SMP sampling period at LGR.
(6) End of SMP sampling at Lower Granite Dam.

Figure B11: Historical Run of Year Yearling Outmigration Distribution at Lower Granite Dam.

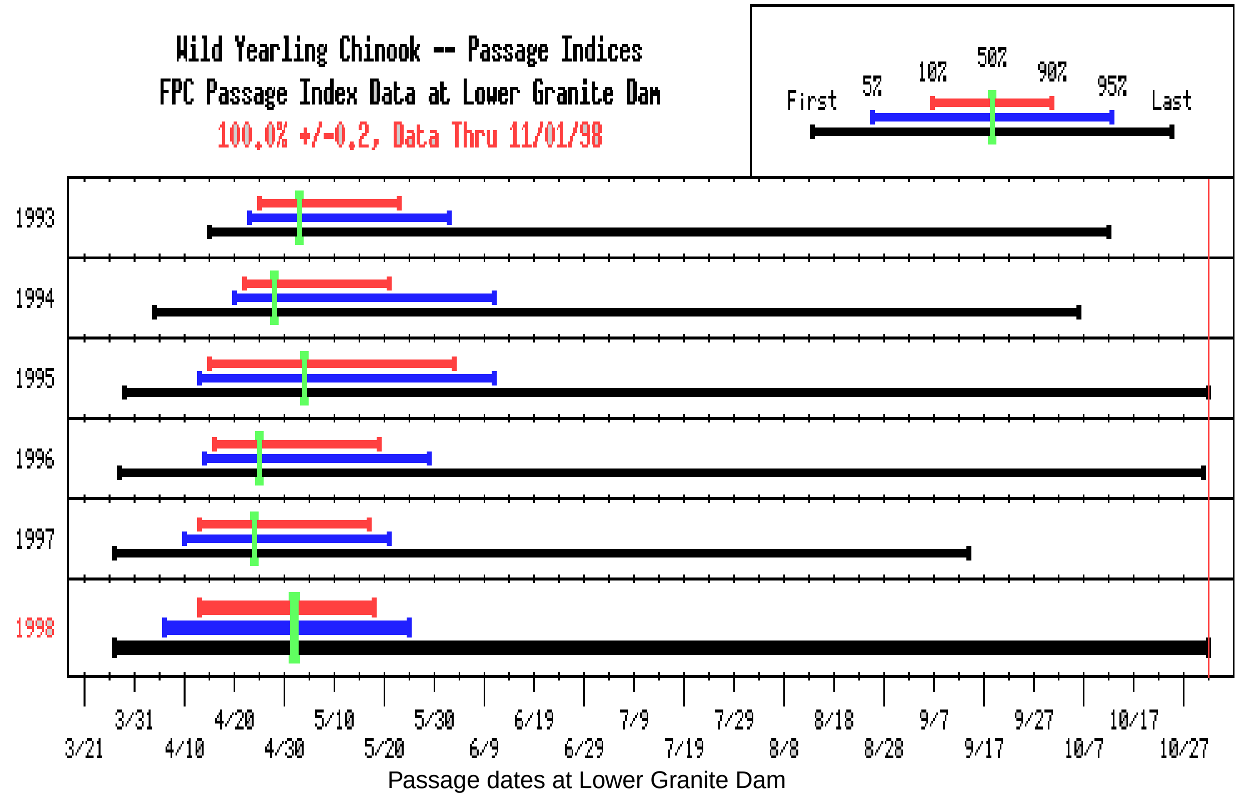


Table B11: Historical wild yearling chinook outmigration timing characteristics at Lower Granite Dam using historical passage indices for 1993-98.

Detection Year	Passage Dates							Duration Middle 80% (days)	Total LGR Passage	BOS Date (1)	EOS Date (2)
	First	5%	10%	50%	90%	95%	Last				
1993	4/15	4/23	4/25	5/03	5/23	06/02	10/12	29	374138	4/15	10/31
1994	4/04	4/20	4/22	4/28	5/21	06/11	10/06	30	334022	4/02	11/01
1995	3/29	4/13	4/15	5/04	6/03	06/11	11/01	50	865290	3/29	11/01
1996	3/28	4/14	4/16	4/25	5/19	05/29	10/31	34	214106	3/26	11/01
1997	3/27	4/10	4/13	4/24	5/17	05/21	09/14	35	80861	3/27	10/31
1998	3/27	4/06	4/13	5/02	5/18	05/25	11/01	36	373736	3/27	11/11

(1) Beginning of SMP sampling at Lower Granite Dam.
(2) End of SMP sampling at Lower Granite Dam.

Figure B12: Historical Run of Year Steelhead Outmigration Distribution at Lower Granite Dam.

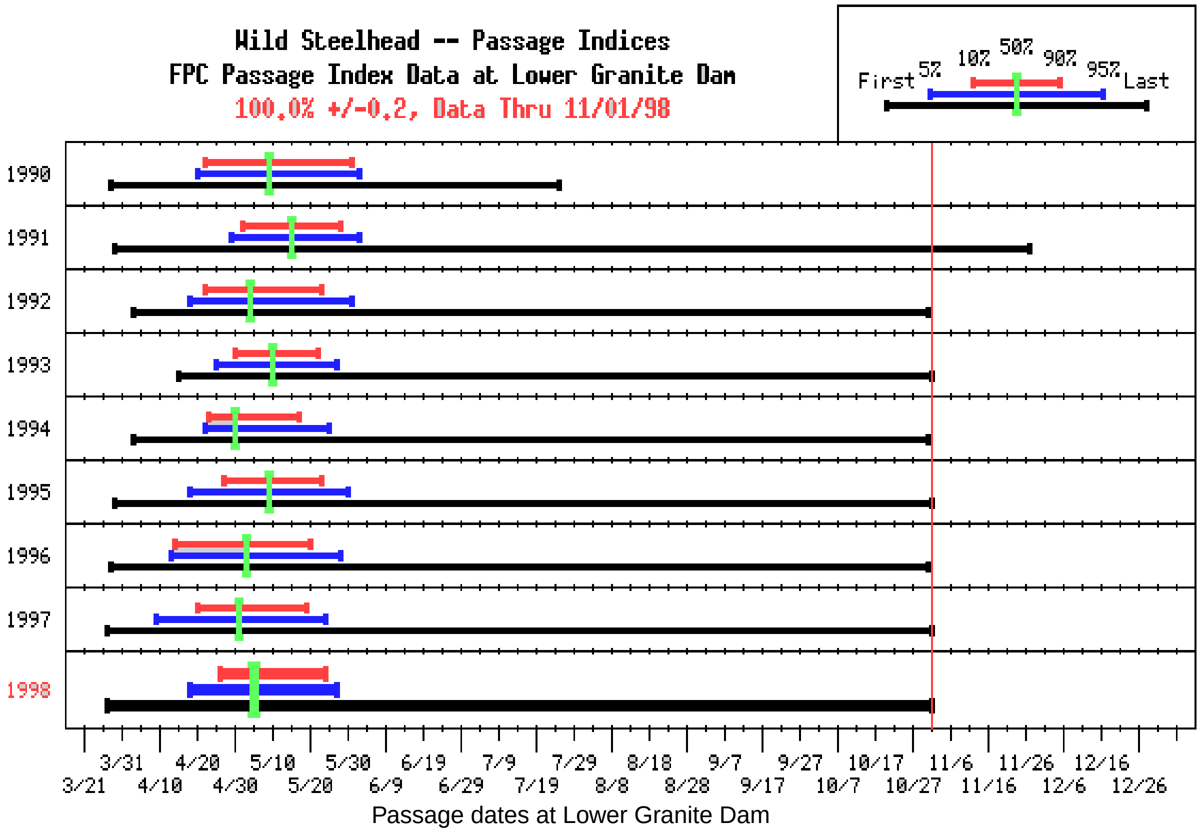


Table B12: Historical wild steelhead outmigration timing characteristics at Lower Granite Dam using historical passage indices for 1993-98.

Detection Year	Passage Dates							Duration Middle 80% (days)	Total LGR Passage	BOS Date (1)	EOS Date (2)
	First	5%	10%	50%	90%	95%	Last				
1990	3/28	4/20	4/22	5/09	5/31	06/02	07/25	40	698242	3/28	07/25
1991	3/29	4/29	5/02	5/15	5/28	06/02	11/27	27	628771	3/28	11/27
1992	4/03	4/18	4/22	5/04	5/23	05/31	10/31	32	583740	4/02	10/31
1993	4/15	4/25	4/30	5/10	5/22	05/27	11/01	23	583457	4/15	10/31
1994	4/03	4/22	4/23	4/30	5/17	05/25	10/31	25	517244	4/02	11/01
1995	3/29	4/18	4/27	5/09	5/23	05/30	11/01	27	485203	3/29	11/01
1996	3/28	4/13	4/14	5/03	5/20	05/28	10/31	37	525732	3/26	11/01
1997	3/27	4/09	4/20	5/01	5/19	05/24	11/01	30	435069	3/27	10/31
1998	3/27	4/18	4/26	5/05	5/24	05/27	11/01	40	698242	3/27	11/11

(1) Beginning of SMP sampling at Lower Granite Dam.
(2) End of SMP sampling at Lower Granite Dam.

Appendix C

Daily expansion factors for the spillway flow at Lower Granite Dam, 1998.

1998 expansions from March 31 through November 1. The numbers are the adjustment factors which are multiplied by the raw counts of fish at Lower Granite dam. See computational method in text: equation (2).

Date	Daily Expansion Factor	Date	Daily Expansion Factor	Date	Daily Expansion Factor
03/31/1998	1.882737	04/24/1998	3.873737	05/18/1998	3.495266
04/01/1998	2.135967	04/25/1998	4.043823	05/19/1998	3.379734
04/02/1998	2.010400	04/26/1998	3.964416	05/20/1998	3.533989
04/03/1998	2.020849	04/27/1998	3.751452	05/21/1998	3.612548
04/04/1998	2.020079	04/28/1998	3.706071	05/22/1998	3.420486
04/05/1998	2.015502	04/29/1998	3.795530	05/23/1998	3.415714
04/06/1998	3.443607	04/30/1998	3.961218	05/24/1998	3.376884
04/07/1998	4.674374	05/01/1998	4.013439	05/25/1998	3.328138
04/08/1998	5.089107	05/02/1998	3.933909	05/26/1998	3.397545
04/09/1998	5.306430	05/03/1998	3.508055	05/27/1998	3.524491
04/10/1998	5.378121	05/04/1998	3.475115	05/28/1998	3.521038
04/11/1998	5.050460	05/05/1998	3.454897	05/29/1998	3.462325
04/12/1998	5.221070	05/06/1998	3.445506	05/30/1998	3.521121
04/13/1998	4.559767	05/07/1998	3.398738	05/31/1998	3.460061
04/14/1998	3.789582	05/08/1998	3.381590	06/01/1998	3.446319
04/15/1998	3.713800	05/09/1998	3.381461	06/02/1998	3.542246
04/16/1998	3.744504	05/10/1998	3.347523	06/03/1998	3.721550
04/17/1998	3.743743	05/11/1998	3.337352	06/04/1998	3.604451
04/18/1998	3.900624	05/12/1998	3.436011	06/05/1998	3.814015
04/19/1998	3.901711	05/13/1998	3.378500	06/06/1998	3.887907
04/20/1998	3.821091	05/14/1998	3.537607	06/07/1998	4.198696
04/21/1998	4.007478	05/15/1998	3.375988	06/08/1998	4.001026
04/22/1998	3.879330	05/16/1998	3.342276	06/09/1998	3.894024
04/23/1998	3.484764	05/17/1998	3.298778	06/10/1998	4.384119
06/11/1998	4.203638	07/08/1998	7.110702	08/04/1998	4.884144
06/12/1998	4.336841	07/09/1998	7.480453	08/05/1998	4.913892
06/13/1998	4.288228	07/10/1998	7.546190	08/06/1998	4.920396

Date	Daily Expansion Factor
06/14/1998	4.146176
06/15/1998	3.928725
06/16/1998	3.949108
06/17/1998	4.086951
06/18/1998	4.611325
06/19/1998	4.772018
06/20/1998	4.811452
06/21/1998	2.452653
06/22/1998	2.454749
06/23/1998	2.545374
06/24/1998	2.562120
06/25/1998	4.234877
06/26/1998	2.464190
06/27/1998	2.245837
06/28/1998	2.264857
06/29/1998	2.523360
06/30/1998	2.690311
07/01/1998	5.331182
07/02/1998	5.283894
07/03/1998	5.245758
07/04/1998	5.076213
07/05/1998	5.489510
07/06/1998	5.968277
07/07/1998	6.829247
08/31/1998	4.992429
09/01/1998	4.992007
09/02/1998	4.987643
09/03/1998	4.989016
09/04/1998	4.987868

Date	Daily Expansion Factor
07/11/1998	7.239747
07/12/1998	7.200039
07/13/1998	7.482004
07/14/1998	7.323314
07/15/1998	7.309125
07/16/1998	7.079744
07/17/1998	8.024827
07/18/1998	6.349388
07/19/1998	4.570410
07/20/1998	4.634063
07/21/1998	4.774246
07/22/1998	4.754941
07/23/1998	4.729436
07/24/1998	4.605812
07/25/1998	4.566300
07/26/1998	4.849590
07/27/1998	4.797125
07/28/1998	4.734807
07/29/1998	4.832755
07/30/1998	4.710818
07/31/1998	4.645715
08/01/1998	4.589250
08/02/1998	4.906972
08/03/1998	4.958387
09/27/1998	4.936554
09/28/1998	4.942479
09/29/1998	4.896732
09/30/1998	4.903541
10/01/1998	4.880950

Date	Daily Expansion Factor
08/07/1998	4.928447
08/08/1998	4.942513
08/09/1998	4.975803
08/10/1998	4.933525
08/11/1998	4.919070
08/12/1998	4.898620
08/13/1998	4.956718
08/14/1998	4.973950
08/15/1998	4.923129
08/16/1998	4.921922
08/17/1998	4.942678
08/18/1998	4.911556
08/19/1998	4.911993
08/20/1998	4.877375
08/21/1998	4.883692
08/22/1998	4.910269
08/23/1998	4.918444
08/24/1998	4.947317
08/25/1998	4.966733
08/26/1998	4.951322
08/27/1998	4.973200
08/28/1998	4.986073
08/29/1998	4.972631
08/30/1998	4.981316
10/24/1998	4.128298
10/25/1998	3.994704
10/26/1998	4.010206
10/27/1998	4.027470
10/28/1998	3.854813

Date	Daily Expansion Factor
09/05/1998	4.985494
09/06/1998	4.996762
09/07/1998	4.997542
09/08/1998	4.996894
09/09/1998	4.983881
09/10/1998	4.979392
09/11/1998	4.981193
09/12/1998	4.984329
09/13/1998	4.983847
09/14/1998	4.971889
09/15/1998	4.982949
09/16/1998	4.977952
09/17/1998	4.970172
09/18/1998	4.942548
09/19/1998	4.948870
09/20/1998	4.950925
09/21/1998	4.947719
09/22/1998	4.973312
09/23/1998	4.967764
09/24/1998	4.958781
09/25/1998	4.929162
09/26/1998	4.922746

Date	Daily Expansion Factor
10/02/1998	4.831711
10/03/1998	4.794647
10/04/1998	4.770685
10/05/1998	4.705861
10/06/1998	4.752647
10/07/1998	4.731700
10/08/1998	4.685947
10/09/1998	4.669606
10/10/1998	4.552651
10/11/1998	4.524433
10/12/1998	4.415875
10/13/1998	4.367254
10/14/1998	4.327919
10/15/1998	4.066969
10/16/1998	4.235961
10/17/1998	4.063600
10/18/1998	4.016440
10/19/1998	4.321964
10/20/1998	4.277944
10/21/1998	4.260593
10/22/1998	4.227074
10/23/1998	4.185571

Date	Daily Expansion Factor
10/29/1998	3.793620
10/30/1998	3.746107
10/31/1998	3.754119
11/01/1998	3.611953